U.S. FISH AND WILDLIFE SERVICE SPECIES ASSESSMENT AND LISTING PRIORITY ASSIGNMENT FORM

Scientific Name:

Oncorhynchus clarki virginalis

Common Name:

Rio Grande Cutthroat trout

Lead region:

Region 2 (Southwest Region)

Information current as of:

05/30/2012

Status/Action

___ Funding provided for a proposed rule. Assessment not updated.

___ Species Assessment - determined species did not meet the definition of the endangered or threatened under the Act and, therefore, was not elevated to the Candidate status.

___ New Candidate

_X_ Continuing Candidate

___ Candidate Removal

> ___ Taxon is more abundant or widespread than previously believed or not subject to the degree of threats sufficient to warrant issuance of a proposed listing or continuance of candidate status
>
> ___ Taxon not subject to the degree of threats sufficient to warrant issuance of a proposed listing or continuance of candidate status due, in part or totally, to conservation efforts that remove or reduce the threats to the species
>
> ___ Range is no longer a U.S. territory
>
> ___ Insufficient information exists on biological vulnerability and threats to support listing
>
> ___ Taxon mistakenly included in past notice of review
>
> ___ Taxon does not meet the definition of "species"
>
> ___ Taxon believed to be extinct
>
> ___ Conservation efforts have removed or reduced threats

___ More abundant than believed, diminished threats, or threats eliminated.

Petition Information

___ Non-Petitioned

_X_ Petitioned - Date petition received: 02/24/1998

90-Day Positive:

12 Month Positive:05/14/2008

Did the Petition request a reclassification? **No**

For Petitioned Candidate species:

Is the listing warranted(if yes, see summary threats below) **Yes**

To Date, has publication of the proposal to list been precluded by other higher priority listing? **Yes**

Explanation of why precluded:

Higher priority listing actions, including court-approved settlements, court-ordered and statutory deadlines for petition findings and listing determinations, emergency listing determinations, and responses to litigation, continue to preclude the proposed and final listing rules for this species. We continue to monitor populations and will change its status or implement an emergency listing if necessary. The Progress on Revising the Lists section of the current CNOR (http://endangered.fws.gov/) provides information on listing actions taken during the last 12 months.

Historical States/Territories/Countries of Occurrence:

- **States/US Territories**: Colorado, New Mexico, Texas
- **US Counties**:County information not available
- **Countries**:Country information not available

Current States/Counties/Territories/Countries of Occurrence:

- **States/US Territories**: Colorado, New Mexico
- **US Counties**: Colfax, NM, Lincoln, NM, Mora, NM, Otero, NM, Rio Arriba, NM, Sandoval, NM, San Miguel, NM, Santa Fe, NM, Sierra, NM, Taos, NM
- **Countries**:Country information not available

Land Ownership:

Public:
Bureau of Land Management, 6.1 kilometers (3.8 miles; 1 percent)
U.S. Forest Service, 653 kilometers (406 miles; 59 percent)
National Park Service, 22.8 kilometers (14.2 miles; 3 percent)

State: (Colorado, New Mexico), 13 kilometers (8 miles; 1 percent)
Private: 398 kilometers (247 miles; 36 percent)

Lead Region Contact:

Lead Field Office Contact:

NM ESFO, Susan Oetker, (505) 761-4761, susan_oetker@fws.gov

Biological Information

Species Description:

Cutthroat trout are distinguished by the red to orange slashes in the gular folds beneath the lower jaw (Behnke 2002, p. 139). Rio Grande cutthroat trout have irregular shaped spots that are concentrated behind the dorsal fin, smaller less numerous spots located primarily above the lateral line anterior to the dorsal fin, and basibranchial teeth that are minute or absent (Sublette et al. 1990, p. 53; Behnke 2002, p. 207). Rio Grande cutthroat trout are light rose to red-orange on the sides and pink or yellow-orange on the belly (Behnke 2002, p. 207).

Taxonomy:

The Rio Grande cutthroat trout, one of 14 subspecies of cutthroat trout, was originally described in 1856 (Behnke 2002, p. 210) and is native to the Rio Grande, Pecos River, and Canadian River basins in New Mexico and Colorado (Sublette et al. 1990, p. 53; Behnke 2002, p. 208). Rio Grande cutthroat trout has the distinction of being the first North American trout recorded by Europeans (Behnke 2002, p. 207). In 1541, Francisco de Coronado’s expedition discovered Rio Grande cutthroat trout in the upper Pecos River (Behnke 2002, p. 207). The first specimens that were collected for scientific purposes came from Ute Creek in Costilla County, Colorado, in 1853. We have carefully reviewed the available taxonomic information to reach the conclusion that Rio Grande cutthroat trout is a valid taxon.

Habitat/Life History:

Little is known specifically about the life history of Rio Grande cutthroat trout. As is true of other subspecies of cutthroat trout, it is found in clear cold streams. Unlike some species of cutthroat trout, such as the Bonneville(*Oncorhynchus clarki utah*) and Yellowstone (*O. c. bouvieri*), Rio Grande cutthroat trout did not originally inhabit large lake systems. However, they have been introduced into coldwater lakes and reservoirs. They spawn as high flows from snowmelt recedes, typically from the middle of May to the middle of June in New Mexico (NMDGF 2002, p. 17). Spawning is probably keyed to day length, water temperature, elevation, and runoff (Pritchard and Cowley 2006, p. 25). The size of mature females ranges from 10.7-26 centimeters (cm) (4.21-10.27 inches (in.)) (Pritchard and Cowley 2006, p. 25). Number of eggs per female varies greatly depending on the size and age of the fish (Pritchard and Cowley 2006, pp. 25-26).

It is unknown if Rio Grande cutthroat trout spawn every year or if some portion of the population spawns every other year, as has been recorded for westslope cutthroat trout (*Oncorhynchus clarki lewisi*) (McIntyre and Rieman 1995, p. 1). Likewise, while it is assumed that females mature at age 3, they may not spawn until age 4 or 5 as seen in westslope cutthroat trout (McIntyre and Rieman 1995, p. 3). Sex ratio also is unknown with certainty, but based on field data, a ratio skewed towards more females might be expected (Pritchard and Cowley 2006, p. 27). Although Yellowstone (Gresswell 1995, p. 36), Bonneville (Schrank and Rahel 2004, p.

1532), and westslope (Bjornn and Mallet 1964, p. 73; McIntyre and Rieman 1995, p. 3) cutthroat trout subspecies are known to have a migratory life history phase, it is not known if Rio Grande cutthroat trout once had a migratory form when there was connectivity among watersheds.

Most cutthroat trout are opportunistic feeders, eating both aquatic invertebrates and terrestrial insects that fall into the water (Sublette et al. 1990, p. 54). Rio Grande cutthroat trout evolved with Rio Grande chub (Gila pandora) and longnose dace (Rhinichthys cataractae) (all basins); Rio Grande sucker (Catastomus plebius) (Rio Grande basin); white sucker (C. commersonii) and creek chub (Semotilus atromaculatus) (Pecos and Canadian basins); and the southern redbelly dace (Phoxinus erythrogaster) (Canadian River basin) (Rinne 1995, p. 24). Many of these fish have either been extirpated from streams with Rio Grande cutthroat trout or are greatly reduced in number (Sublette et al. 1990, p. 162; Calamusso and Rinne 1999, pp. 233-236). It is not known if they once were an important component of Rio Grande cutthroat trout diet. Other subspecies of cutthroat trout become more piscivorous (fish eating) as they mature (Moyle 1976, p. 139; Sublette et al. 1990, p. 54) and cutthroat trout living in lakes will prey heavily on other species of fish (Echo 1954, p. 244). It is possible that native cyprinids (i.e., chubs, minnows, and dace) and suckers were once important prey items for Rio Grande cutthroat trout. Growth of cutthroat trout varies with water temperature and availability of food. Most populations of Rio Grande cutthroat trout are found in high elevation streams. Under these conditions growth may be relatively slow and time to maturity may take longer than is seen in subspecies that inhabit lower elevation (warmer) streams.

Typical of trout, Rio Grande cutthroat trout require several types of habitat for survival: spawning, nursery or rearing, adult, and refugium. Spawning habitat consists of clean gravel (little or no fine sediment present) that ranges from 6 to 40 millimeters (mm) (0.24-1.6 in.) (NMDGF 2002, p. 17). Nursery habitat is usually at the stream margins where water velocity is low and water temperature is slightly warmer. Harig and Fausch (2002, pp. 542, 543) found that water temperature may play a critical role in the life history of the young-of-year cutthroat. Streams with mean daily temperature in July of less than 7.8 degrees Celsius (ºC) (46 degrees Fahrenheit (ºF)) may not have successful recruitment (survival of individuals to sexual maturity and joining the reproductive population) or reproduction in most years. Adult habitat consists of pools with cover and riffles for food production and foraging. The primary form of refugium is deep pools that do not freeze in the winter and do not dry in the summer or during periods of drought. This refugium in the form of large deep pools is also necessary for survival. Lack of large pools may be a limiting factor in headwater streams (Harig and Fausch 2002, p. 543). Refugium may also be a downstream reach or a connected adjacent stream that has maintained suitable habitat in spite of adverse conditions.

Based on our current knowledge of habitat and life history characteristics of the Rio Grande cutthroat trout, important characteristics of habitat appear to include coolwater streams with abundant aquatic invertebrates and other prey, deep pools that do not freeze in winter or dry in summer, clean gravel for spawning, and nursery habitat at the stream margins.

Historical Range/Distribution:

The historical distribution of Rio Grande cutthroat trout is not known with certainty. In general, it is assumed that Rio Grande cutthroat trout occupied all streams capable of supporting trout in the Rio Grande, Pecos River, and Canadian River basins (Alves et al. 2007, p. 9). The Pecos River is a tributary of the Rio Grande, so a historical connection between the two basins likely existed. Although no early museum specimens document its occurrence in the headwaters of the Canadian River, it is almost certainly native there as well (Behnke 2002, p. 208). The Canadian River, tributary to the Mississippi River, has no connection with the Rio Grande. It is possible that through headwater capture (a tributary from one watershed joins with a tributary from another) there may have been natural migration of fish between the Pecos and Canadian headwater streams (Behnke 2002, p. 208). Because there are remnant Rio Grande cutthroat trout populations throughout the headwaters of the Rio Grande basin, historically, these fish most likely dispersed through the Rio Grande into the tributary streams.

There is evidence that Rio Grande cutthroat trout may have occurred in Texas (Garrett and Matlock 1991, p. 404; Behnke 1967, pp. 5, 6) and Mexico (Behnke 1967, p. 4). However, no specimens were collected to document their presence in these locations with certainty. Their potential occupancy in these locations is based on fluvial connections and on historical articles that describe the presence of trout that could have been Rio Grande cutthroat trout.

Current Range Distribution:

No Rio Grande cutthroat trout are currently reported from Texas or Mexico. In Colorado and New Mexico, streams currently capable of supporting trout are at elevations of 1,829 meters (m) (6,000 feet (ft)) and above; on north-facing slopes they are found in streams at elevations of 1,671 m (5,500 ft) and above. Historically (circa 1800), 43 percent of Rio Grande cutthroat trout populations occupied streams 2,438 m (8,000 ft) or less in elevation (Alves et al. 2007, p. 18). Currently, only about 1.6 percent of the populations are in streams less than 2,438 m (8,000 ft) (Alves et al. 2007, p. 18). Conservation populations (those populations with 10 percent or less introgression (hybridization) from nonnative trout genes) are concentrated in elevations from 2,743–3,048 m (9,000–10,000 ft) (Alves et al. 2007, p. 18). Conservation populations of Rio Grande cutthroat trout occupy approximately 10 percent of their historical habitat (Alves et al. 2007, p. iii). Because Rio Grande cutthroat trout are now restricted to headwater, first, and second order streams that are narrow and small compared to the larger third, and fourth order streams they once occupied, the absolute loss of habitat is much greater than stream miles might indicate. Currently, the southernmost distribution of Rio Grande cutthroat trout (introgressed populations) occurs in Animas Creek, Sierra County, New Mexico, and Indian Creek on the Mescalero Apache Indian Reservation in Otero County, New Mexico. Distribution in the southern portion of the range is limited and no conservation populations currently exist south of Santa Fe, New Mexico.

Population Estimates/Status:

The Rio Grande Cutthroat Trout Conservation Team completed a rangewide status report (Alves et al. 2007) concerning the Rio Grande cutthroat trout. This status report summarizes information provided by 15 fisheries professionals from Colorado and New Mexico having specific knowledge of Rio Grande cutthroat trout. Additionally, a comprehensive database (referred to as “2010 database” in this finding) is compiled annually by these professionals of all the data on Rio Grande cutthroat trout collected that year. There are approximately 105 Rio Grande cutthroat trout populations that are considered to be core (less than1 percent introgressed) or conservation populations (less than10 percent introgression) distributed in high elevation streams of New Mexico and Colorado (Alves et al. 2007, p. 26). As described above, these populations occupy approximately 10 percent of historical habitat and face a variety of threats including fragmentation and isolation, small population size, presence of nonnative trout, whirling disease, poor habitat conditions, fire, drought, and the effects of climate change which are discussed in detail below. Tables 1 and 2 display those populations with the fewest threats and which appear to be the most secure. Only those populations with greater than 2,500 fish are presented in the tables (see discussion below under Factor A for the justification). There are no nonnative trout present in these populations and none have tested positive for whirling disease. In our May 14, 2008, status review (73 FR 27905) we presented a table (Table 1) that displayed fewer populations with greater than 2,500 fish (see “Threats” section below for a discussion of why this is an appropriate benchmark to gauge population persistence) in stream lengths greater than 9.6 kilometers (km) (6 miles (mi)) (length criterion is discussed below). The population size displayed in the 2008 status review represented the number of adults only (individuals over 120 mm (4.7 in)), not the total population (73 FR 27905). The tables presented below represent a correction to the data presented in the 2008 status review. To derive the numbers below we assumed the adult population size was approximately 20 percent of the total population (Cowley 2007, p. 424) and therefore divided the total adult number by 0.2 to arrive at the total population number.

We have displayed all core and conservation populations with greater than 2,500 Rio Grande cutthroat trout; however, as discussed below, populations in stream lengths less than 9.6 km (6 mi) may be compromised in their ability to provide the necessary habitat for all life stages in times of stress (e.g., reduced flows, increased temperature) and therefore the viability of the populations in the shorter stream segments over the long term is questionable. When successful reproduction and recruitment does not occur every year, the number of individuals needed to sustain the genetic integrity of the population increases (Cowley 2007, p. 428). Short stream segments are less likely to support this increased number of fish (carrying capacity becomes limiting) and more likely to have year class failure (habitat becomes limiting).

Table 1. Rio Grande cutthroat trout core and conservation populations in Colorado with greater than 2,500 fish and no nonnative trout present (summarized from 2010 database).

Stream name	Total Population	Stream length km (mi)	Stream width (ft)	Habitat condition	Barrier
Torcido	30,209	13.2 (8.2)	5-10	Good	Insufficient flow
Medano	28,458	17.4 (10.8)	5-10	Excellent	Insufficient flow
San Francisco	19,100	25.3 (15.7)	5-10	Fair	Water diversion
Cross	18,377	12.6 (7.8)	<5	Fair	Insufficient flow
Jaroso	8,455	8.0 (5.0)	5-10	Good	Culvert
Osier	16,195	6.2 (3.8)	5-10	Good	Culvert
Cuates	4,180	6.2 (3.8)	5-10	Excellent	Manmade dam
Alamosito	5,110	5.6 (3.5)	5-10	Good	Culvert
East Middle	5,885	5.1 (3.2)	5-10	Fair	Waterfall
Cascade	11,860	4.7 (2.9)	5-10	Good	Waterfall
Nabor	5,930	3.7 (2.3)	<5	Excellent	Manmade dam
Torcido	8,935	3.4 (2.1)	5-10	Good	Drying
Rhodes Gulch	3,135	3.4 (2.1)	<5	Fair	waterfall

Table 2. Rio Grande cutthroat trout core and conservation populations in New Mexico with greater than 2,500 fish and no nonnative trout present(summarized from 2010 database).

Stream name	Total Population	Stream length km (mi)	Stream width (ft)	Habitat condition	Barrier
El Rito	24,462	12.7 (7.9)	10-15	Good	Manmade barrier
Canones	16,348	10.8 (6.7)	5-10	Fair	Manmade barrier
Costilla	14,940	14.6 (9.1)	<5	Good to excellent	Manmade barrier
Polvadera	10,875	12.1 (7.5)	<5	Poor	waterfall
Jacks	7,519	11.3 (7.0)	5-10	Good	Manmade barrier
Ute	6,301	13.8 (8.6)	5-10	Good	None
Rio de Truchas	3,460	10.5 (6.5)	5-10	Fair	Water diversion
Canjilon	8,580	8.0 (5.0)	5-10	Good	None
Alamitos	16,290	7.2 (4.5)	10-15	Good	Water diversion
Clear	4,507	7.6 (4.7)	5-10	Good	Bedrock
Columbine	3,622	7.1 (4.4)	10-15	Good	Manmade barrier
San Cristobal	3,558	6.4 (4.0)	10-15	Excellent	Dewatered
Rito Angostura	7650	6.4 (4.0)	5-10	Good	waterfall
Powderhouse	4,195	6.3 (3.9)	<5	Good	Manmade barrier
Pecos River	5,695	6.3 (3.9)	5-10	Good	waterfall
Policarpio	3,520	4.8 (3.0)	5-10	Good	Manmade barrier
Bitter	2,675	2.7 (1.7)	<5	Poor	Chemical

Threats

A. The present or threatened destruction, modification, or curtailment of its habitat or range:

The historical range of Rio Grande cutthroat trout has been greatly reduced over the last 150 years. Populations have been lost because of water diversions, stream drying, dams, habitat degradation, changes in hydrology, hybridization with rainbow trout (Oncorhynchus mykiss), or competition with brown (Salmo trutta) and brook trout (Salvelinus fontinalis) (Pritchard and Cowley 2006, p. 3). As described above, conservation populations are now concentrated in elevations from 2,743–3,048 m (9,000–10,000 ft) (Alves et al. 2007, p. 18). High-elevation streams (above 2,743 m (9,000 ft)) are subject to extreme and fluctuating environmental conditions including forest fires, freezing, and dewatering (Novinger and Rahel 2003, p. 779). In addition, headwater mountain streams often lack critical resources such as deep pools (Harig and Fausch 2002, p. 546) and provide insufficient refuge from catastrophic disturbance (Pritchard and Cowley 2006, p. 17).

Historically, many watersheds supporting Rio Grande cutthroat trout contained streams that were connected. For example, in Colorado, the Trinchera, Conejos, Culebra, Costilla, and Alamosa Rivers would have been connected through the upper Rio Grande, forming a vast network of streams (Alves et al. 2007, p. 10). As a consequence of habitat loss (primarily dewatering because of agricultural diversions), these watersheds are now isolated from each other, and Rio Grande cutthroat trout are restricted to fragments of streams (Alves et al. 2007, pp. 12, 29). Ninety-three percent of the conservation populations, representing 80 percent of occupied miles, are in isolated stream fragments (Alves et al. 2007, p. 29). No populations are considered to have strong connectivity (i.e., greater than or equal to five connected streams with open migration corridors) (Alves et al. 2007, pp. 29, 77). One population (Costilla Creek, a recently completed restoration project) has a moderate degree of connectivity (four to five connected streams), which is an increase of one population compared to 2008. Seven populations have very little connectivity (two to three connected streams, infrequent straying of adults may occur) (Alves et al. 2007, pp. 29, 43, 77).

Habitat fragmentation reduces the total area of habitat available, reduces habitat complexity, and prevents gene flow (Saunders et al. 1991, p. 25; Burkey 1995, pp. 527, 528; Rieman and McIntyre 1995, p. 293; Dunham et al. 1997, pp. 1126, 1127; Frankham et al. 2002, p. 310; Noss et al. 2006, p. 219). Fragmentation accelerates extinction, especially when movement of fish among fragments is not possible, as is the case with Rio Grande cutthroat trout (Burkey 1995, p. 540; Frankham et al. 2002, p. 314). Isolated populations are vulnerable to extinction through demographic stochasticity (random changes in the population structure, e.g., uneven male to female ratios); environmental stochasticity (random changes in the fishes' surroundings) and catastrophes (e.g., fires, stream drying, freezing); loss of genetic heterozygosity (genetic diversity) and rare alleles (inherited forms of a genetic trait); and human disturbance (Shaffer 1987, p. 71; Rieman et al. 1993, pp. 6-7; Burkey 1995, pp. 527, 528; Dunham et al. 1997, p. 1130; Frankham et al. 2002, pp. 310-324). Completely isolated fragments are the most severe form of fragmentation because the isolation prevents fish from mating with other fish carrying different genes, thereby preventing new genes from entering the isolated population (Frankham et al. 2002, p. 314).

Apart from the lack of gene flow that fragmentation causes, the short length of the fragments and small sizes of populations that they support are also of concern for Rio Grande cutthroat trout. Seventy-one percent of Rio Grande cutthroat trout conservation populations occupy stream segments of 8.1 km (5 mi) or less (median 6.2 km (4.2 mi)) (Alves et al. 2007, p. 26). Several researchers have found that population viability of cutthroat trout is correlated with stream length (Hilderbrand and Kershner 2000, p. 515; Young et al. 2005, p. 2405; Cowley 2007, p. 10). Stream length is important because trout need a variety of habitats to complete their life cycle (i.e., spawning, rearing, adult, refugium) (Rieman and McIntyre 1995, p. 293; Horan et al. 2000, p. 1251; Harig and Fausch 2002, p. 546; Young et al. 2005, p. 2406). The shorter the stream, the more likely it is that one or more of the Rio Grande cutthroat trout's required habitats is either missing or inadequate for completion of the species' life cycle (Hilderbrand and Kershner 2000, p. 513). This is particularly true in high-elevation streams, which are narrower and shallower than larger, lower elevation streams. The longer the stream, the more complexity it encompasses, and the higher the probability that no particular habitat type limits the population and that reproduction and recruitment occur every year.

Hilderbrand and Kershner (2000, p. 515) estimated 8.3 km (5.1 mi) were required to maintain a population of 2,500 cutthroat trout when fish abundance was high (0.3 fish/m (0.09 fish/ft)). Adding a 10 percent loss rate, to account for emigration and mortality, increased the length up to 9.3 km (5.8 mi) in order to maintain 2,500 fish. For abundances of 0.2 fish/m (0.06 fish/ft) and 0.1 fish/m (0.03 fish/ft), the corresponding length increased to 12.5 km (7.8 mi) and 25 km (15.5 mi), respectively (assuming no losses) (Hilderbrand and Kershner 2000, p. 15). Young et al. (2005, p. 2405) found that to maintain a population of 2,500 cutthroat trout, 8.8 km (5.5 mi) of stream were needed. Cowley (2007, p. 10) determined that in stream widths of approximately 2 m (6.6 ft) (average width of most Rio Grande cutthroat trout streams), a stream length of 11 km (6.8 mi) would be needed to support a population of 2,750 fish. Because the majority (71 percent) of Rio Grande cutthroat trout conservation populations occur in short stream fragments of 8.1 km (5 mi) or less, these studies indicate that stream fragmentation (resulting in short stream lengths) pose a threat to Rio Grande cutthroat trout conservation populations.

It can be argued that if a short stream segment has more than 2,500 fish, it must have all the habitat requirements needed to support a population of that size. While this argument has merit when looking at short time frames, the Service is obligated to consider conservation of species in the foreseeable future. The foreseeable future is the time frame in which predictions can be reasonably relied upon because they are based on careful extrapolation grounded in data and logic (U.S. Department of the Interior 2009, p. 8). We must look at the foreseeability of the threats and the foreseeability of the impact of those threats on species. Of particular concern to the Rio Grande cutthroat trout are the effects that climate change will have in the foreseeable future (discussed in detail below). Although certain short stream segments may be supporting populations of 2,500 fish under relatively benign climatic conditions, we have little certainty that under more stressful conditions, in particular widespread, long lasting drought or increased water temperatures, short stream segments would continue to provide all the necessary habitat to maintain populations greater than 2,500 fish.

Longer streams support larger populations (Harig and Fausch 2002, p. 546; Young et al. 2005, p. 2405). Population size is a major determinant of species persistence (Reed et al. 2003, p. 23). Population persistence decreases as population size decreases (Rieman and McIntyre 1993, p. 15).

Population stability

Long-term persistence of a population depends on having a sufficient number of individuals to avoid inbreeding depression, which decreases population viability, and to maintain genetic variation (Franklin 1980, pp. 135-148; Frankham et al. 2002, pp. 190-192; Reed 2005, pp. 563, 564). Genetic variability within a population is necessary for adaptability (Reed 2005, p. 564; Cowley 2007). Genetic variation will be lost through time in isolated populations, and the loss occurs more quickly in small populations than in large populations (Rieman and Allendorf 2001, p. 761). When a population is greatly reduced in size (bottlenecked), genetic diversity is decreased (Frankham et al. 2002, p. 183)

In our June 11, 2002, candidate status review (67 FR 39938), the Service concluded that a population size of 2,500 fish would ensure long-term persistence of Rio Grande cutthroat trout, (i.e., would reduce the risks associated with small population size alone). Since that time other peer-reviewed literature has been published that allows us to further evaluate this number. Reed et al. (2003, p. 30), in a review of 102 vertebrate species, estimated that sufficient habitat should be present to allow for approximately 7,000 breeding age adults in order to ensure long-term species persistence. Cowley (2007, p. 424) found that a population size of 2,500 Rio Grande cutthroat trout failed to meet the desired long-term effective population size (number of adults actually contributing offspring to the population) of at least 500. A minimum population size of 2,750 was sufficient if there was infrequent loss of year classes (all the individuals of a population of fishes born or hatched in the same year). He found that a larger population size was required as survival rate of young fish (one year or less) decreased. He concluded that managing for Rio Grande cutthroat trout population sizes in the range of 8,000 to 16,000 would be more likely to ensure population viability when there are low to intermediate survival rates of young fish. While any population number we might use to assess the status of the subspecies is unlikely to satisfy all interested parties, we believe a population size of 2,500 fish continues to be a reasonable standard by which to evaluate the populations. While the range of acceptable standards may range from 2,500 to 16,000, there is relative certainty that populations below 2,500 are likely at risk and may not be contributing to long-term persistence of the subspecies.

It has been argued that small, isolated populations have persisted for decades (Patten and Sloane 2007, p. 3). However, Rio Grande cutthroat trout populations have only been monitored and intensively managed during the last 50 years or less, and habitat conditions and stressors are very different from historical conditions. Consequently, long-term persistence cannot be appropriately assessed. In addition, although some isolated populations may have persisted for centuries, these populations are probably exceptions (Hilderbrand and Kershner 2000, p. 517). To assume all isolated populations will behave similarly may lead to insufficient protection (Hilderbrand and Kershner 2000, p. 517).

The Service has evaluated the data presented by Alves et al. (2007), supplemental information requested related to the 2008 database, and additional data received since the 2008, 2009, and 2010 status reviews. Based on our knowledge of Rio Grande cutthroat trout populations we conclude:
(1) There has been at least a 90 percent loss of historical habitat caused by a wide array of biological and physical alterations to habitat;
(2) The majority (71 percent of the populations) of Rio Grande cutthroat trout conservation populations are in isolated fragments less than 8 km (5 mi) long, and fragmentation is a threat to long-term persistence;
(3) Populations are concentrated in high elevation (2,438 to 3,048 m (8,000 to 10,000 ft)) headwater streams that provide marginal habitat, especially in regards to the number and depth of pools critical for trout survival in times of environmental extremes.

Habitat Condition

Many Rio Grande cutthroat trout conservation populations currently occupy lands administered by Federal agencies. Of the total 1,110 km (690 mi) of occupied habitat, 698 km (434 mi) (63 percent) are under Federal jurisdiction, with the majority (59 percent) occurring within National Forests (Alves 2007, p. 2). Rio Grande cutthroat trout occupy 6.1 km (3.8 mi) of land administered by the Bureau of Land Management (BLM), 30.5 km (19 mi) managed by the National Park Service, and 397 km (247 mi) that are privately owned.

Land uses associated with each conservation population were identified in Alves et al. (2007 p. 49, Table 33), but the impact of the activities was not evaluated in relation to individual populations or the conservation of the subspecies. These activities include nonangling recreation (e.g., camping, hiking, ATV use), angling, livestock grazing, roads, timber harvest, dewatering, and mining . Only 3 populations (3 percent) were judged as having no land use activities within a zone that would influence the stream habitat. Many populations have more than one land use occurring in the area.

An evaluation of habitat quality was conducted for currently occupied habitat (Alves et al. 2007, p. 20). The evaluation considered both natural habitat features and human disturbances, including land use practices. A stream ranked excellent if it had ample pool habitat, low sediment levels, optimal temperatures, and quality riparian habitat. Good habitat quality had some attributes that are less than ideal, and fair habitat has a greater number of attributes that are less than ideal. Poor habitat quality is found where most habitat attributes reflect inferior conditions. Approximately 224 km (139 mi) (20.2 percent of occupied habitat) received an excellent habitat rating. Good habitat conditions were found in 426 km (265 mi) (38.4 percent of occupied habitat), and fair habitat conditions were found in 335 km (208 mi) (30.1 percent of occupied habitat). Poor conditions were found in 35 km (22 mi) (3.2 percent of occupied habitat), and habitat conditions in 90 km (56 mi) (8.1 percent) were unknown (Alves 2007, p. 20). The majority of occupied habitat (58.6 percent) is considered in good or excellent condition (Alves et al. 2007, p.20).

The Service also reviewed 19 detailed stream survey reports that were conducted by the Santa Fe and Carson National Forests from 2001 to 2006. Although these surveys represent only about one quarter of the conservation populations in New Mexico (19 of 84 populations), both large (Pecos River, Rio de las Vacas, Comanche Creek) and small (Yerba and Manzanita Creeks) streams are represented. Therefore, these surveys provide additional insight into the habitat condition on U.S. Forest Service (Forest Service) lands. Of the 19 streams surveyed, the most consistent problem was lack of pool habitat. Of the 19 streams, 18 had less than the 30 percent pool habitat (range 1–21 percent) needed to be considered properly functioning trout streams. For eight of these streams, a target value of 30 percent pool habitat was not considered appropriate because they were first or second order streams (i.e., headwater streams), which often have few pools naturally because they occur on high gradient slopes. In four of these eight streams, the pool habitat ranged from 1–3 percent, and the reports noted that even for headwater streams this was an insufficient number of pools.

In most streams (16 of 19) the average residual pool volume, which represents initial pool depth if the stream were too dry, met the Forest Service standard of 0.3 m (1 ft) or greater. However, the deepest average residual pool volume was only 0.67 m (2.2 ft) and the mean depth of pools for all 19 streams was 0.39 m (1.3 ft), indicating that the majority of pools (holding and refugia) are shallow.

Pools are recognized as important overwintering habitat and also are holding areas for trout when streams dry. Not only are the number of pools consistently fewer than desirable, but they are also shallow and thus provide limited refugia in times of stream freezing or drying. Lack of deep pools could affect year class survival. As noted by Cowley (2007, p. 9) loss of a year class of fish would suggest that longer stream length is needed to provide adequate habitat for long-term population persistence. However, as mentioned above, the sample size (19 streams) is relatively small, and it is not known if the results accurately represent Rio Grande cutthroat trout streams rangewide.

Livestock grazing occurs within the zone of influence (area around the stream in which activities influence stream habitat) of 87 percent of the Rio Grande cutthroat trout populations (Alves 2007, p. 49). We recognize that improper grazing does cause adverse impacts (e.g., loss of cover, increased sedimentation, loss of riparian vegetation) to some individual populations of Rio Grande cutthroat trout, especially during drought conditions when the cattle tend to concentrate in riparian areas. Several Forest Service stream surveys noted that impacts by livestock and wildlife were causing localized problems, but grazing was not cited as causing problems throughout any stream. Specific information on grazing impacts to Rio Grande cutthroat trout habitat on a rangewide basis is not available. We have no information that leads us to conclude that improper grazing is a significant threat to Rio Grande cutthroat trout rangewide.

Timber harvest and associated road building occur in 19 percent and 58 percent of the conservation populations, respectively. These activities have also led to the deterioration of Rio Grande cutthroat trout habitat. However, timber harvest in the National Forests has declined appreciably in the last 20 years. As an example, on the Santa Fe and Carson National Forests, there has been a total of 3.2 hectares (ha) (8 acres (ac)) clear cut since 1995 (Fink 2008, pp. 2, 3). The average amount of timber cut per year from 1984 to 1994 in these forests was 27.6 and 19 million board feet, respectively. From 1995 to 2005, the average amount cut per year was 3.5 and 0.09 million board feet, respectively (Fink 2008, pp. 2, 3). While the effects of past logging practices may still be evident on the landscape in some locations, we conclude that timber harvest is not currently a threat to Rio Grande cutthroat trout populations.

Roads and off-highway vehicles can have negative impacts on stream habitat primarily through increased sedimentation, which degrades spawning habitat. Nonangling recreation (which includes hiking and camping as well as off-highway vehicle use) is present near 90 percent of the conservation populations. On November 9, 2005, the Forest Service published a revised rule regarding travel management on their lands (70 FR

68264). One of the primary purposes of this rule is to protect natural resources. The final rule requires the designation of roads, trails, and areas that are open to motor vehicle use by class of vehicle and, if appropriate, time of year. Use of motor vehicles off designated routes will be prohibited (70 FR 68264). The Service has begun consultation on the Travel Management Plans proposed by National Forests in Forest Service Region 3 (Arizona and New Mexico) and protecting aquatic resources is an important component of these plans. While roads have been identified as an area of concern for some streams (e.g., Tio Grande, Rio Grande del Rancho), we conclude that the current levels of road construction and maintenance is not a threat to Rio Grande cutthroat trout populations rangewide.

Rangewide habitat quality is still difficult to accurately assess. Although an insufficient amount of pool habitat exists on the majority of streams sampled by the Forest Service in New Mexico, we cannot draw the same conclusion rangewide at this time because of lack of data. Alves et al. (2007, pp. 1-144) did not identify a lack of pools as a systematic problem. While land management practices have clearly improved and have less direct impact on Rio Grande cutthroat trout streams, some streams are still recovering from past land management practices. Therefore, we conclude that there is insufficient information to indicate that habitat quality currently is a significant threat to Rio Grande cutthroat trout rangewide.

Drought

The relatively short-term drought of the early 2000s negatively affected or extirpated 14 Rio Grande cutthroat trout populations in Colorado and New Mexico (Japhet et al. 2007, pp. 42-44; Patten et al. 2007, pp. 14-40). A fifteenth population is thought to have been extirpated in 2006 by complete freezing caused by low flow in the winter (Ferrell 2006, p. 11). The number of streams impacted may have been greater, because managers survey a fraction of the conservation populations in any given year.

We assume that small streams (1.5 m (5 ft) wide or less) are more susceptible to drying, increased water temperatures, and freezing than larger ones and that stream width is an indicator of risk. Decreased streamflow reduces the amount of habitat available for aquatic species, and water quality (e.g., temperature, dissolved oxygen) may become unacceptable in declining flow. Approximately 27 conservation populations are in streams that are 1.5 m (5 ft) or less in width throughout their entire length (2010 database). An additional 29 stream segments that are tributaries to the conservation populations are also less than 1.5 m (5 ft) in width (2010 database). Although not all small streams have equal risk, small headwater streams, especially those with an inadequate number of deep pools, are most likely to lose suitable habitat. Even if streams do not dry or freeze completely, stream length can be truncated during drought and cold temperatures, and many fish can perish, greatly reducing the population number and reducing genetic diversity (Frankham et al. 2002, p. 183).

Because of the documented extirpation and population reductions of Rio Grande cutthroat trout caused by drought, the possibility of more widespread drought accompanying climate change, and the lack of a rangewide plan to address drought, we conclude that drought is a threat to Rio Grande cutthroat trout throughout its range (discussed in “Climate Change” section below).

Fire

Wildfires are a natural disturbance in forested watersheds. However, since the mid-1980s, wildfire frequency in western forests has nearly quadrupled compared to the average frequency during the period 1970–1986. The total area burned is more than six and a half times the previous level (Westerling et al. 2006, p. 941). In addition, the average length of the fire season during 1987–2003 was 78 days longer compared to that during 1970–1986 and the average time between fire discovery and control was 29.6 days longer (Westerling et al. 2006, p. 941). Westerling et al. (2006, p. 942) found that wildfire sensitivity was related to snowmelt timing with 56 percent of fires and 72 percent of burned area occurring in early snowmelt years. Early spring snowmelt is strongly associated with spring temperature (Stewart et al. 2004, p. 218; Westerling et al. 2006, p. 942). Westerling et al. (2006, p. 942) concluded that there are robust statistical associations between wildfire and climate in western forests and that increased fire activity over recent decades reflects responses to climate change (discussed further in the "Climate Change" section below).

In the Southwest, the fire season is followed by the monsoon season (July to August). Consequently, denuded watersheds are susceptible to heavy precipitation leading to severe floods and ash flows. Although fish may survive the fire, ash and debris flows that occur after a fire can eliminate populations of fish from a stream (Rinne 1996, p. 654; Brown et al. 2001, p. 142; Forest Service 2006, p. 32; Patten et al. 2007, p. 33), and the fire suppression activities (e.g., fire retardant, water removal, road construction) may also impact stream ecosystems (Buhl and Hamilton 2000, pp. 410-416; Backer et al. 2004, pp. 942, 943). Wildfires within the range of Rio Grande cutthroat trout have impacted or eliminated fish populations (Ferrell 2006, p. 32; Japhet et al. 2007, p. 20; Patten et al. 2007, pp. 33, 36), and the effects of large fires are recognized as a threat to greenback cutthroat trout (Oncorhynchus clarki stomias) populations in Colorado (Young and Guenther-Gloss 2004, p. 194). Imperiled fish populations can be rescued if ash flows are imminent, but a rescue and evacuation plan should be in place (e.g., Brooks 2004, pp. 1-15).

Dunham et al. (2007, p. 342) found significantly elevated stream temperatures for at least a decade after a stand-replacing wildfire because of the lack of stream shading. In addition, the authors suggest that longer term (over 20 years) increases in stream temperatures are likely in systems where debris flows or severe floods completely eliminate streamside vegetation and reorganize the channel. Rainbow trout were found to be resilient and recolonized the burned streams within one year of extirpation in spite of elevated water temperatures (Dunham et al. 2007, p. 343). Dunham et al. (2003a, pp. 188, 189) suggested that fire poses a greater threat to fish populations when habitat is fragmented. Moyle and Light (1996, p. 157) argued that habitat degradation favors nonnative fishes and that species with narrow habitat requirements are expected to be more sensitive to habitat alteration caused by fire than generalist species, such as rainbow trout (Dunham et al. 2003a, p. 189).

Fire risk can be reduced through fuels reduction and prescribed burns. The National Forests in New Mexico have active programs to improve forest health. As an example, 28,314 ha (69,965 ac) have undergone fuel-reduction treatment, thereby improving watershed conditions associated with 100 km (62 mi) of stream, and an additional 58,912 ha (145,575 ac) are planned for treatment to improve conditions associated with an additional 128 km (79.5 mi) of stream (Ferrel 2002, p. 12). Such techniques have been found to reduce fire severity even under extreme weather conditions in low-elevation ponderosa pine forests (Schoennagel et al. 2004, p. 669). However, for mid-elevation, mixed-severity fire regimes, fuel-reduction treatments had virtually no effect on the 2002 Hayman Fire (Colorado), and extreme climate can override the influence of stand structure and fuels on fire behavior (Schoennagel et al. 2004, pp. 672, 673). Climate variation, not fuel levels, is seen as the dominant influence on fire frequency and severity in subalpine forests (Schoennagel et al. 2004, p. 666).

Wildfires that eliminate nonnative fish provide the opportunity to reclaim streams for Rio Grande cutthroat trout. The 1996 Dome Fire in the Jemez Mountains (Santa Fe National Forest) extirpated the fish residing in Capulin Canyon. In 2006, after 10 years of habitat recovery, 100 Rio Grande cutthroat trout from Canones Creek were stocked into Rio Capulin, adding 11.2 km (7.0 mi) of occupied habitat in New Mexico (Patten et al. 2007, p. 94). In addition, ash flows after the 2004 Peppin Fire in the Capitan Wilderness (Lincoln National Forest) eliminated all fish from Pine Lodge Creek (Patten et al. 2007, pp. 255-258). Rio Grande cutthroat trout were stocked into Pine Lodge Creek in 2007 and surveys in 2008 indicated they were persisting. It was initially thought that all trout were also eliminated from Copeland Creek by the Peppin Fire, although brook trout were found there in 2008 (Patten 2009).

Although we recognize that Rio Grande cutthroat trout evolved in a landscape that included fire, wildfire intensity and size are likely changing because of increased fuel loads and climate change (see "Climate Change" section below). Wildfire today is much more of a threat than it was historically to Rio Grande cutthroat trout because of existing habitat loss, fragmentation, and climate change. These multiple stressors may overwhelm the species' resilience to disturbance such as fire (Rieman et al. 2005, pp. 2, 3). Although fire may also provide opportunity for repatriation of Rio Grande cutthroat trout by eliminating nonnative fish, total elimination of nonnative fish from fire-affected streams is not guaranteed, and it may take many years for the habitat to become suitable. For these reasons, we conclude that wildfire is a significant threat to Rio Grande cutthroat trout throughout its range.

Summary of Factor A

Rio Grande cutthroat trout populations have been and continue to be affected by habitat fragmentation and isolation, drought, and fire. Rio Grande cutthroat trout conservation populations occupy a fraction of their historical habitat, they are confined primarily to small high-elevation streams with marginal habitat, they are highly fragmented, and the stream segments they occupy are short in length. All of these factors work to reduce gene flow between populations and reduce the ability of populations to recover from catastrophic events, thus threatening their long-term persistence. Detailed habitat surveys, although not available rangewide, are uniformly consistent in documenting a lack of pools in streams occupied by Rio Grande cutthroat trout. Deep pools are considered a critically important element of Rio Grande cutthroat trout habitat. Additionally, drought and fire are considered threats and are expected to increase in response to climate change (as discussed in the “Climate Change” section below). Based on the best scientific and commercial information available to us, we conclude that the present or threatened destruction, modification, or curtailment of its habitat or range is a threat to the continued existence of Rio Grande cutthroat trout.

B. Overutilization for commercial, recreational, scientific, or educational purposes:

No commercial harvest occurs for Rio Grande cutthroat trout. Recreational angling occurs on approximately 84 percent of the populations (Alves et al. 2007, p. 49). Fishing regulations in New Mexico and Colorado appropriately manage recreational angling. For example, many of the streams with Rio Grande cutthroat trout are “catch and release.” Those that are not have a two (New Mexico) or four (Colorado) fish limit. Many of the streams with pure populations of Rio Grande cutthroat trout are remote and angling pressure is light. For these reasons, angling is not considered a threat to Rio Grande cutthroat trout.

Collection of Rio Grande cutthroat trout for scientific or educational purposes is controlled by a strict permitting process that prevents excessive sampling. In addition, advancements in molecular technology have resulted in the need for only a small clipping from a fin to provide sufficient material to perform molecular analysis of genetic purity. To test for whirling disease (see “Disease” section below for further discussion), usually 60 fish are collected and sacrificed. However, to minimize the collection of Rio Grande cutthroat trout during whirling disease testing, nonnative trout are collected preferentially over Rio Grande cutthroat trout, or sample sites are selected below a barrier that protects a population of Rio Grande cutthroat trout from nonnative trout. In some situations fewer than 60 Rio Grande cutthroat trout will be collected and sacrificed for testing. For these reasons, overutilization for scientific purposes is not considered a threat to Rio Grande cutthroat trout.

Summary of Factor B

No commercial harvest occurs for Rio Grande cutthroat trout, fishing regulations in New Mexico and Colorado minimize the impact of recreational angling, and scientific collection of Rio Grande cutthroat trout for scientific or educational purposes is controlled by a strict permitting process that prevents excessive sampling. Based on the best scientific and commercial information available to us, we conclude that Rio Grande cutthroat trout is not threatened by overutilization for commercial, recreational, scientific, or educational purposes.

C. Disease or predation:

Disease

Whirling disease is of great concern to fishery managers in western States. Whirling disease is caused by the nonnative myxosporean parasite, Myxobolus cerebralis. This parasite was introduced to the United States from Europe in the 1950s and requires two separate hosts, a salmonid fish and an aquatic worm (Tubifex tubifex) to complete its life cycle. Spores of the parasite are released from infected fish when they die. The spores are ingested by T. tubifex where they undergo transformation in the gut to produce actinosporean triactionomyxons (TAMs). Trout are infected either by eating the worms (and TAMs) or through contact with water in which TAMs are present. Once M. cerebralis is present, total year class failure can occur among susceptible species, such as Rio Grande cutthroat trout, under the proper suite of environmental conditions (Nehring 2009, p. 2). Studies have shown that these conditions are not very restrictive and do not necessarily involve environmental degradation (Nehring 2009, p. 2).

The myxosporean parasite became widely distributed in Colorado in the early 1990s through the stocking of millions of catchable size trout from infected hatcheries (Nehring 2009, p. 1). Up to 2001, it was estimated that whirling disease infection had negatively impacted recruitment of wild rainbow and brook trout fry (small recently hatched fish) in 560–600 km (350-400 mi) of stream in Colorado (Nehring 2009, p. 2). In 2006, the number of sites that tested positive for whirling disease was considerably higher than in any of the previous field seasons (Nehring 2007, p. 11). Whirling disease is also present in several streams in New Mexico (Patten and Sloane 2007, p. 11). Laboratory (DuBey et al. 2007, pp. 1411, 1412) and field (Thompson et al. 1999, pp. 323-325) experiments have shown that Rio Grande cutthroat trout are very susceptible to whirling disease.

Among the four lineages (I, III, V, and VI) of T. tubifex known to occur in Colorado, New Mexico, and other states, lineage III is the only one susceptible to infection by M. cerebralis (DuBey and Caldwell 2004, p. 183; Nehring 2009, p. 7). Because T. tubifex are typically found in degraded habitat with higher levels of sediment and warmer temperatures, it had been hypothesized that Rio Grande cutthroat trout were provided some level of protection because they occur in high elevation cold-water streams (67 FR 39943, Service 2002). However, extensive sampling of tubificid worms in Colorado does not support this hypothesis. Nehring (2009, p. 7) collected tubificid worm samples from over 100 sites in Colorado, including streams occupied by Rio Grande cutthroat trout. He stratified his results by 305 m (1,000 ft) elevation groups from 1,829 m (6,000 ft) to 3,657 m (12,000 ft) (e.g., 1,829–2,134 m (6,000–7,000 ft), 2,134–2,438 m (7,001–8,000 ft), etc.). Lineage III worms had the greatest abundance, outnumbering all of the other lineages combined, at all elevations. The number of sites with lineage III worms was approximately the same at all elevations from the 1,829–2,134 m (6,000–7,000 ft) band up to the 3,048–3,353 m (10,000–11,000 ft) band (Nehring 2009, p. 7) indicating that high elevation coldwater streams do not provide protection from lineage III worms.

Eighty-eight percent of the conservation populations are judged to have very limited risk from whirling disease or other potential diseases because the pathogens are not known to exist in the watershed or a barrier blocks upstream fish movement (Alves et al. 2007, p. 38). Six populations are at minimal risk because they are greater than 10 km (6.2 mi) from the pathogen or they are protected by a barrier, but the barrier may be at risk of failure (Alves et al. 2007, p. 38). Eight populations were identified as being at moderate risk because whirling disease had been identified within 10 km (6.2 mi) of occupied habitat (Alves et al. 2007, p. 38). In 2006, it was discovered that whirling disease had infected brook trout and Rio Grande cutthroat trout in Placer Creek, Colorado, a conservation population, and in 2007 it was chemically treated to remove infected fish and nonnative brook trout.

In 2002, the Pecos, Cebolla, San Juan, Cimarron, Red, and Canones Rivers in New Mexico were listed as being infected with whirling disease (67 FR 39943, June 11, 2002). By 2007, more than 80 streams and lakes had been tested for the disease (Patten and Sloane 2007, pp. 10-13). North Bonito Creek, Brazos River, and Los Pinos River were added to the list of streams testing positive for whirling disease. Canones and Jacks

Creeks, which both tested positive in 2000, tested negative in 2005 and 2003, respectively (Patten and Sloane 2007, pp. 10-13). Of the streams listed, Rio Cebolla, Pecos River, and Cimarron River are occupied by Rio Grande cutthroat trout upstream above barriers.

NMDGF policies and regulations prohibit the stocking of any whirling disease positive fish in the State of New Mexico (Patten and Sloane 2007, p. 10). All private facilities must maintain a pathogen-free certification. The Seven Springs Hatchery, which is used for Rio Grande cutthroat trout broodstock, has tested negative on all occasions since it was refurbished (Patten and Sloane 2007, p. 10). In Colorado, stocking of whirling disease positive fish in protected habitats, which include native cutthroat trout waters, is prohibited (Japhet et al. 2007, p. 12). Colorado and New Mexico have websites, brochures, and information in their fishing regulations regarding whirling disease and what anglers can do to prevent its spread. In addition, both States have regulations regarding the stocking of fish by private landowners that are designed to eliminate the importation of whirling disease positive fish. It states clearly in the fishing regulations that it is illegal to stock fish in public waters without prior permission from a State agency.

Whirling disease remains a concern for Rio Grande cutthroat trout populations. One Rio Grande cutthroat trout conservation population was infected in Colorado, and restoration efforts were immediately implemented to address the issue. Although widespread increases in M. cerebralis have not been seen, additional infected sites have been documented. Because of the limited level of infection currently, whirling disease is not seen as a significant threat to populations rangewide. However, climate change and warmer stream temperature may facilitate the spread of whirling disease in the future (discussed in the “Disease” section in Factor E below).

Predation

Brown trout are piscivores and are the most likely predator of Rio Grande cutthroat trout. Additionally, brown trout have been found to have a significant negative impact on the condition of coexisting Rio Grande cutthroat trout through harassment (e.g., chasing) (Shemai et al. 2007, pp. 315-323; McHugh and Budy 2005, p. 2788). It is probable that larger brown trout prey on young Rio Grande cutthroat trout and, unchecked, brown trout can depress population levels. Warmer water temperatures in the future may give brown trout a greater competitive advantage over Rio Grande cutthroat trout (discussed in the “Climate Change” section below). Although, we have insufficient information at this time to conclude that predation by brown trout is currently a significant threat to Rio Grande cutthroat trout, it is an additional stressor to populations.

Summary of Factor C

One population of Rio Grande cutthroat trout has been infected with whirling disease, and eight conservation populations are considered to be at moderate risk of infection. Although whirling disease is currently limited in distribution and effect, it has the potential to become a more widespread problem due to warmer waters that could result from climate change (discussed in the “Climate Change” section below). We have insufficient information to conclude that predation in of itself is a significant threat at this time, although it is an additional stressor to populations. Based on the best scientific and commercial information available to us, we conclude that, although the status of Rio Grande cutthroat trout has not yet been significantly affected by disease, Rio Grande cutthroat trout is likely to be threatened by disease in the foreseeable future.

D. The inadequacy of existing regulatory mechanisms:

The NMDGF and the Colorado Division of Wildlife (CDOW) have authority and responsibility for the management of Rio Grande cutthroat trout. Rio Grande cutthroat trout is designated as a species of special concern by the State of Colorado and of special management concern by the State of New Mexico. The agencies’ capabilities include the regulation of fishing, law enforcement, research, conservation, and educational activities relating to Rio Grande cutthroat trout. Policies regarding the stocking of nonnative fish (no nonnatives are stocked in areas of Rio Grande cutthroat trout populations), minimization of exposure to whirling disease and other diseases, and broodstock management are in place in both States. In 2004, the Conservation Plan for Rio Grande Cutthroat Trout in Colorado (CDOW 2004, pp. 1-75) was approved by the Director of CDOW. The goal of the plan is to assure the long-term persistence of Rio Grande cutthroat trout throughout its historical range by preserving genetic integrity, reducing population fragmentation, and providing suitable habitat to support self-sustaining populations (Japhet et al. 2007, p. ii). In 2002, New Mexico approved a management plan currently being implemented that will “facilitate long range cooperative, interagency conservation of Rio Grande cutthroat trout” (NMDGF 2002).

Rio Grande cutthroat trout populations have been lost because of stream drying (Japhet et al. 2007, pp. 42-44), and other trout populations in the Southwest have been extirpated as the result of ash flows following fire (Brown et al. 2001 p. 142). Imperiled fish populations can be rescued from streams (Brooks 2004, pp. 1-15; Japhet et al. 2007, p. 20). In the face of widespread drought or fire (discussed in the “Climate Change” section below), it is expected that many streams would be affected at one time, as seen in the 2002 drought (Japhet et al. 2007, pp. 42-44; Patten et al. 2007, pp. 14-40). An emergency rescue and evacuation plan is not in place for Rio Grande cutthroat trout, nor do we anticipate that this strategy would be effective in eliminating the threat of stream drying or post-fire ash flows in the face of widespread drought.

In 2003, a rangewide conservation agreement was signed by CDOW, NMDGF, Forest Service, the Service, BLM, National Park Service, and Jicarilla Apache Nation. The purpose of the agreement is to facilitate cooperation and coordination among State, Federal, and Tribal agencies in the conservation of Rio Grande cutthroat trout. The Conservation Team has met several times and the “Range-wide Status of Rio Grande Cutthroat Trout (Oncorhynchus clarki virginalis): 2007” is a product of the team’s cooperative effort (Alves et al. 2007). The conservation agreement was officially extended in 2009.

Regulatory Mechanisms Involving Land Management

Numerous State and Federal laws and regulations help to minimize adverse effects of land management activities on Rio Grande cutthroat trout. Federal laws that protect Rio Grande cutthroat trout and their habitats include the Clean Water Act (33 U.S.C. 1251 et seq.), Federal Land Policy and Management Act (43 U.S.C. 1701 et seq.), National Forest Management Act (16 U.S.C. 1600 et seq.), Wild and Scenic Rivers Act (16 U.S.C. 1271 et seq.), Wilderness Act (16 U.S.C. 1131 et seq.), and the National Environmental Policy Act (42 U.S.C. 4321 et seq.). Approximately 59 percent of Rio Grande cutthroat trout habitat occurs on lands managed by Federal agencies. The majority of those lands are managed by the Forest Service. Rio Grande cutthroat trout occur over a large geographic area within the Rio Grande, Santa Fe, and Carson National Forests in Colorado and New Mexico. Rio Grande cutthroat trout is designated as a sensitive species on all Forest Service lands.

Threats to depletion of streamflow can be reduced by the Forest Service using its authorities, if any, to further secure additional instream flows in Colorado. Rio Grande cutthroat trout conservation populations are protected by State instream flow water rights or Forest Service reserved water rights along 620 km (385 mi) in 63 stream segments (approximately 70 percent of occupied habitat) within the Rio Grande basin in Colorado. Most of the remaining Rio Grande cutthroat trout conservation populations that are not associated with instream flow water rights are found on private property within the boundaries of the old Spanish Land Grants where natural resource stewardship is practiced. Regulatory controls of water quality in Colorado are implemented by the Colorado Water Quality Control Division and Commission. Water quality standards are in place to protect the maintenance of aquatic life in coldwater environments, and special resource restrictions are also available to provide further site-specific protection to water quality (Japhet et al. 2007, p.18).

Summary of Factor D

The NMDGF, CDOW, and Forest Service are actively managing Rio Grande cutthroat trout and its habitat.

They also have authority for and are undertaking fisheries management, research, and educational and law enforcement activities designed to improve the conservation status of the species. There is a rangewide conservation agreement that also involves the Service and other parties. Existing regulations, authorities, and policies address current threats to the species that are subject to regulatory control. However, climate change (discussed below) will potentially affect populations throughout the range of this species. There are no regulatory mechanisms in place that address climate change.

E. Other natural or manmade factors affecting its continued existence:

Nonnative species

The introduction of nonnative trout is widely recognized as one of the leading causes of range reduction in cutthroat trout subspecies (Griffith 1988, pp. 134, 137; Lassuy 1995, p. 394; Henderson et al. 2000, pp. 584, 585; Dunham et al. 2002, p. 374; Peterson et al. 2004, p. 769). Dunham et al. (2004, pp. 18-26) provide an overview of the effect of nonnatives on headwater systems in North America. Since the late 1800s, fishery managers introduced nonnative salmonids (trout and salmon species) into lake and stream habitats of Rio Grande cutthroat trout. Nonnative rainbow, brook, and brown trout and Yellowstone cutthroat trout have been introduced extensively throughout the range of Rio Grande cutthroat trout, and they compete (brook and brown trout) and hybridize (rainbow and other cutthroat subspecies) with Rio Grande cutthroat trout. Forty-six of 120 conservation populations (38 percent) have nonnative trout present (2010 database). When Rio Grande cutthroat trout occur in the same stream as nonnative trout, Rio Grande cutthroat trout typically occupy the colder, headwater reaches and the nonnative trout occupy areas downstream (Griffith 1988, p. 135; Dunham et al. 1999, p. 885).

Competition from nonnative trout, especially brook trout, is recognized as a threat to Rio Grande cutthroat trout (Behnke 2002, p. 147; Peterson et al. 2004, pp. 768, 769). When brook trout invade streams occupied by cutthroat trout, the native cutthroat trout decline, or are displaced (Griffith 1988, p. 136; Harig et al. 2000b, pp. 994, 998, 999; Dunham et al. 2002, p. 378; Peterson et al. 2004, p. 769; Young and Guenther-Gloss 2004, p. 193; Fausch et al. 2006, p. 6). Brook trout are the most common nonnative trout sympatric (co-occurring) with Rio Grande cutthroat trout populations in Colorado (2010 database). Brook trout reduce recruitment and interannual survival of juvenile cutthroat trout, leading to a reduction in population size (Peterson et al. 2004, p. 769). Experiments where brook trout were removed showed an increase in the survival of juvenile cutthroat trout (Peterson et al. 2004, p. 767). Paroz (2005, p. 22) found that mean density and relative weight of Rio Grande cutthroat trout were lower in populations sympatric with brook trout. Several Rio Grande cutthroat trout conservation populations have been identified as at risk and declining because of brook trout (Alves et al. 2002, pp. 1-4).

Nehring (2008, Table17) collected data from 25 Rio Grande cutthroat trout conservation populations in Colorado from 2003 to 2007 to document if young-of-year were present and the number of cohorts present in streams. Surveys were conducted from late July to September; young-of-year would be observed if they were present. Of the 25 populations surveyed, young-of-year were not recorded in 9 of the streams (Nehring 2008, Table 17). Two of the nine streams did not have nonnative fish present, and nonnatives were present in the other seven. It is clear from his data that, in general, the number of cohorts observed was far fewer in streams that had nonnative trout compared to those without nonnative trout. Although not comprehensive, these data highlight two important issues: loss of a year class is not uncommon, and fewer cohorts are observed when nonnative trout are present.

In New Mexico, brown trout is the most common nonnative trout present in Rio Grande cutthroat trout conservation populations (summarized from 2010 database). Not only are brown trout piscivores (feed on other fish), but they have also been shown to compete with Rio Grande cutthroat trout for resources such as food and space. Research has shown that Rio Grande cutthroat trout confined with brown trout grew significantly less, while the brown trout grew significantly more, than control fish (Shemai et al. 2007, pp.

315, 320, 321). A similar result was seen in experiments conducted with Bonneville cutthroat trout and brown trout (McHugh and Budy 2005, p. 2788). These results indicate that brown trout represent a threat to Rio Grande cutthroat trout from competition as well as predation (Paroz 2005, p. 34).

The primary threat to Rio Grande cutthroat trout from rainbow trout and other cutthroat trout subspecies is through hybridization and introgression (Rhymer and Simberloff 1996, pp. 83, 97; Muhlfeld et al. 2009, p. 328). The genetic distinctiveness of Rio Grande cutthroat trout can be lost through hybridization (Allendorf et al. 2004, p. 1205). It was recently shown that fitness (reproductive success) of westslope cutthroat trout was reduced by about 50 percent with small amounts of hybridization (20 percent) with rainbow trout (Muhlfeld et al. 2009, p. 329). Of the conservation populations, 79 percent rangewide have been tested and are less than 1 percent introgressed (Alves et al. 2007, p. 31). Nonintrogressed populations occupy 870 km (541 mi), or 78 percent, of the 1,110 km (690 mi) occupied by conservation populations (Alves et al. 2007, p. 31). Another 161 km (100 mi) are occupied by populations that are 90–99 percent genetically pure, and 104 km (65 mi) are occupied by populations that have not been tested but are connected to nonintrogressed populations and have no record of stocking (Alves et al. 2007, p. 34).

To minimize the contact of nonnative trout with Rio Grande cutthroat trout, barriers have been constructed where natural barriers did not already exist in order to prevent nonnatives from invading. Alves et al. (2007, pp. 35, 36) rated the genetic risk for each conservation population. A combination of barrier condition or presence and distance to hybridizing species determined if a population was at moderate or low risk (Alves et al. 2007, p. 80). Populations protected by a complete barrier fell into the no-risk category. Sixty-seven percent had no risk of genetic mixing with nonnative trout, 27 percent were at moderate risk, and 3 percent were at low risk. An additional 3 percent were considered at high risk because they were sympatric with hybridizing species; however, the Service does not consider these to be conservation populations.

Approximately 38 percent of Rio Grande cutthroat trout conservation populations co-occur with nonnative trout (2010 database). Competition, predation, and hybridization with nonnative trout are considered an important source of stress that can depress Rio Grande cutthroat trout population numbers or, under the right circumstances, displace them (Fausch et al. 2006, pp. 9, 10). Although resource agencies remove nonnative trout through electrofishing when they co-occur with cutthroat trout subspecies, seldom if ever is complete removal possible (Patten et al. 2007, p. 104). Peterson et al. (2004, p. 769) showed that over 90 percent of a brook trout population must be removed each year for 3 consecutive years to allow a large cohort of Colorado River cutthroat trout to survive from age 0 to age 2. This level of effort has not been documented for stream segments occupied by Rio Grande cutthroat trout populations (e.g., Japhet et al. 2007, p. 26).

The Service concludes that nonnative fish are a threat to Rio Grande cutthroat trout rangewide based on the following facts:
(1) Nonnative fish are a documented threat to Rio Grande cutthroat trout populations;
(2) Approximately 38 percent of the conservation populations have nonnative trout present;
(3) Mechanical removal cannot remove all of the nonnative fish;
(4) The level of effort required to reduce brook trout populations to levels sufficient for survival of young Rio Grande cutthroat trout is not currently being conducted; and,
(5) The number of streams that need regular treatment exceeds the capability of resource managers at their current staffing levels.

Climate Change

In this section, we discuss the aspects of climate change that will most likely affect the habitat of Rio Grande cutthroat trout. We begin by presenting the evidence that indicates that climate change is occurring globally. We then discuss literature related to climate change that has been published for the Southwest and southern Rocky Mountains that document changes either that have occurred or that researchers predict will occur. Finally, we present data that have been collected for streams occupied by Rio Grande cutthroat trout that indicate that the effects of climate change could exacerbate the threats discussed above.

The Intergovernmental Panel on Climate Change (IPCC) is a scientific body set up by the World Meteorological Organization and the United Nations Environment Program in 1988. It was established because policymakers needed an objective source of information about the causes of climate change, its potential environmental and socioeconomic consequences, and the adaptation and mitigation options to respond to it. The Service considers the IPCC an impartial and legitimate source of information on climate change. In 2007, the IPCC published its Fourth Assessment Report, which is considered the most comprehensive compendium of information on actual and projected global climate change currently available.

Although the extent of warming likely to occur is not known with certainty at this time, the IPCC (2007, p. 5) has concluded that warming of the climate is unequivocal and continued greenhouse gas emissions at or above current rates would cause further warming (IPCC 2007, p. 13). The IPCC also projected that there will very likely be an increase in the frequency of hot extremes, heat waves, and heavy precipitation (IPCC 2007, p. 15). Warming in the Southwest is expected to be greatest in the summer (Christensen et al. 2007, p. 887). Annual mean precipitation is likely to decrease in the Southwest, and the length of snow season and snow depth are very likely to decrease (Christensen et al. 2007, p. 887). Most models project a widespread decrease in snow depth in the Rocky Mountains and earlier snowmelt (Christensen et al. 2007, p. 891).

In consultation with leading scientists from the Southwest, the New Mexico Office of the State Engineer (NMOSE) prepared a report for the Governor (NMOSE 2006), which made the following observations about the effects of climate change in New Mexico:
(1) Warming trends in the American Southwest exceed global averages by about 50 percent (p. 5);
(2) Models suggest that even moderate increases in precipitation would not offset the negative impacts to the water supply caused by increased temperature (p. 5);
(3) Temperature increases in the Southwest are predicted to continue to be greater than the global average (p. 5);
(4) There will be a delay in the arrival of snow and acceleration of spring snowmelt, leading to a rapid and earlier seasonal runoff (p. 6); and
(5) The intensity, frequency, and duration of drought may increase (p. 7).

By the late 21st century, one simulation predicts no sustained snowpack south of Santa Fe or in the Sangre de Cristo Mountains (NMOSE 2006, p. 13). Snowpack would remain in far northern New Mexico and southern Colorado but would be greatly reduced in mass, with a decrease in water mass between one-third and one-half (NMOSE 2006, p. 14).

Three additional reports have been published since the 2008 status review for the Rio Grande cutthroat trout, which focus on New Mexico and Colorado. Enquist et al. (2008, p. iv) found that 93 percent of New Mexico's watersheds have become relatively drier from 1970 to 2006 and that snowpack in New Mexico's major mountain ranges has declined over the past two decades in 98 percent of the sites analyzed. The timing of peak streamflow from snowmelt in New Mexico is an average of one week earlier than in the mid-20th century (Enquist et al. 2008, p. iv). Watersheds with the greatest declines in snowpack are those that have experienced the greatest drying from 1970 to 2006. Enquist and Gori (2008, pp. iii, 25, 32) identified several areas as being particularly vulnerable to climate change, including the Jemez Mountains and the southern Sangre de Cristo Mountains. Both of these mountain ranges have streams with Rio Grande cutthroat trout.

Climate models project Colorado will warm 0.6 to 1.4 °C (1.5 to 3.5 °F) by 2025, relative to the 1950 to 1999 baseline, and 1 to 2.2 °C (2.5 to 5.5 °F) by 2050 (Ray et al. 2008, p. 1). The 2050 projections show summers warming by 1.2 to 2.8 °C (3 to 7 °F), and winters by 0.8 to 2 °C (2 to 5 °F). These projections also suggest that typical summer monthly temperatures will be as warm as, or warmer than, the hottest 10 percent of summers that occurred between 1950 and 1999 (Ray et al. 2008, p. 1). In the geographic area occupied by Rio Grande cutthroat trout in Colorado, air temperatures have warmed by 1 °C (1.8 °F) in the last 30 years (Ray et al. 2008, p. 10). Winter projections show fewer extreme cold months, more extreme warm months, and more strings of consecutive warm winters. Between 1978 and 2004, the onset of spring runoff in

Colorado shifted earlier by two weeks, most likely related to warming spring temperatures (Ray et al. 2008, p. 2). The timing of runoff is projected to shift earlier in the spring, and late summer flows may be reduced. These changes are projected to occur regardless of changes in precipitation (Ray et al. 2008, p. 2).

Hoerling and Eischeid (2007, p. 35) states that in the Southwest, relative to 1990–2005, simulations indicate that a 25 percent decline in streamflow will occur from 2006–2030 and a 45 percent decline will occur from 2035–2060. Seager et al. (2007, p. 1181) show that there is a broad consensus among climate models that the Southwest will get drier in the 21st century and that the transition to a more arid climate is already under way. Only one of 19 models has a trend toward a wetter climate in the Southwest (Seager et al. 2007, p. 1181). Stewart et al. (2004, p. 1152) show that timing of spring streamflow in the western United States during the last five decades has shifted so that the major peak now arrives 1 to 4 weeks earlier, resulting in less flow in the spring and summer. They conclude that almost everywhere in North America, a 10 to 50 percent decrease in spring–summer streamflow will accentuate the seasonal summer dry period with important consequences for warm-season water supplies, ecosystems, and wildfire risks (Stewart et al. 2004, p. 1154). Increases in average mean air temperature of approximately 0.8 °C (1.4 °F) in Colorado (Ray et al. 2008, p. 1) and 1.0 °C (1.8 °F) in New Mexico (Enquist and Gori 2008, p. 4) since 1976 have already been documented. Udall and Gates (2007, p. 7) found that multiple independent data sets confirm widespread warming in the west. Long-term studies (more than 25 years) of Mexican jays (Aphelocoma ultramarina) in Arizona and of yellow-bellied marmots (Marmota flaviventris) in the Rocky Mountains indicate changes in the timing of important life history events (e.g., breeding, emergence from hibernation) for both species related to warmer temperatures (Parmesan and Galbraith 2004, pp. 18, 19).

As we will discuss below, climate change is predicted to have four major effects on the cold water habitat occupied by Rio Grande cutthroat trout:
(1) Increased water temperature;
(2) Decreased streamflow;
(3) A change in the hydrograph (a graphical representation of the distribution of water discharge or runoff over a period of time); and
(4) An increased occurrence of extreme events (fire, drought, and floods).

Increased Water Temperature

Water temperature influences the survival of salmonids in all stages of their life cycle. Alterations in the temperature regime from natural background conditions negatively affect population viability, when considered at the scale of the watershed or individual stream (McCullough 1999, p. 160). Salmonids are classified as coldwater fish with thermal preferences centered around 15 °C (59 °F) (Shuter and Meisner 1992, p. 8). High temperatures suppress appetite and growth, can influence behavioral interactions with other fish (Schrank et al. 2003, p. 100), or can be lethal (McCullough 1999, p. 156). Salmonids inhabiting warm stream segments have higher probabilities of dying from stress (McCullough 1999, p. 156).

Eaton and Scheller (1996, p. 1111) state that the maximum temperature tolerance for cutthroat trout is 23.3 °C (74 °F), but Dunham et al. (2003b, p. 1042) found that Lahontan cutthroat trout (Oncorhynchus clarki henshawi) show signs of stress (decreased growth and appetite and increased mortality) when water temperature exceeds 22 °C (71.6 °F) for even a short time (less than one day). For Bonneville cutthroat trout, the 7-day upper incipient lethal temperature (temperature at which 50 percent of the fish can survive for 7 days) was 24.2 °C (75.6 °F) under constant thermal conditions (Johnstone and Rahel 2003, p. 96). However, when the temperature was cycled daily between 16–26 °C (60.8–78.8 °F) for 7 days, similar to what the trout would experience in high mountain streams, all trout survived (Johnstone and Rahel 2003, p. 97). Dickerson and Vineyard (1999, pp. 519, 520) found a similar result (cycling between 20 and 26 °C (68 and 78.8 °F)) for Lahontan cutthroat trout. Although trout may survive cyclic exposures to high temperatures, growth is slowed or stopped due to the high metabolic costs and reduced food intake (Dickerson and Vineyard 1999, p. 519; Johnstone and Rahel 2003, p. 98).

Although temperature preferences of Rio Grande cutthroat trout have not been specifically studied, their optimum growth temperature (appetite is high and maintenance requirements low) is most likely in the range of 13–15 °C (55.4–59 °F), similar to other cutthroat trout (Meeuwig et al. 2004, p. 213; Bear et al. 2007, p. 1118) and their upper incipient lethal limit is most likely near 23–24 °C (73.4–75.2 °F), as has been found for other subspecies of cutthroat trout (Wagner et al. 2001, p. 434; Johnstone and Rahel 2003, p. 97). Upper incipient lethal limit for rainbow trout ranges from 24–26 °C (75.2–78.8 °F), for brown trout 23–26 °C (73.4–78.8 °F), and for brook trout 24–25 °C (75.2–77 °F) (MuCullough 1999, pp. 47, 48), which means these nonnative trout are better able to tolerate higher water temperatures than cutthroat trout.

The IPCC states that of all ecosystems, freshwater ecosystems will have the highest proportion of species threatened with extinction due to climate change (Kundzewicz et al. 2007, p. 192). Species with narrow temperature tolerances will likely experience the greatest effects from climate change, and it is anticipated that populations located at the margins of species' hydrologic and geographic distributions will be affected first (Meisner 1990a, p. 282). Climate change has already had or is predicted to have negative consequences on coldwater fisheries globally (Nakano et al. 1996, p. 711; Hari et al. 2006, p. 24), across North America (Meisner 1990a, pp. 287, 290; Regier and Meisner 1990, p. 11; Carpenter et al. 1992, p. 124; Eaton and Scheller 1996, p. 1111; O'Neal 2002, p. 3; Poff et al. 2002, p. iv; Chu et al. 2005, p. 303; Preston 2006, pp. 106, 107, 110,111, 115; Reiman et al. 2007, pp. 1553, 1558), and in the Southwest and Rocky Mountains specifically (Keleher and Rahel 1996, p. 1; Rahel et al. 1996, pp. 1116, 1122; O'Neal 2002, pp. 43, 44; Preston 2006, pp. 101,102, 113) through increases in ground and surface water temperature.

The magnitude of habitat loss due to increased water temperature depends on the climate change model used, the model used to predict the relationship between air temperature and water temperature, and the time frame. Keleher and Rahel (1996, p. 4) found that the distribution of salmonids in Wyoming streams was limited to areas where mean July air temperature did not exceed 22 °C (71.6 °F). They projected that for temperature increases of 1, 2, 3, 4, or 5 °C (1.8, 3.6, 5.4, 7.2, 9.0 °F), there would be a corresponding loss of area suitable for salmonids of 16.2, 29.1, 38.5, 53.3, and 68.0 percent, respectively (Keleher and Rahel 1996, p. 4). Rahel et al. (1996) used three approaches to examine potential salmonid habitat loss due to warming in the North Platte River drainage of the Rocky Mountains. They found that there was a loss of 9 to 76 percent of coldwater habitat based on air temperature increases of 1 to 5 °C (33.8 to 41 °F) (Rahel et al. 1996, p. 1120). Other studies have predicted losses of 18–92 percent of suitable natal bull trout (Salvelinus confluentus) habitat (Rieman et al. 2007, p. 1558), and Preston (2006, p. 92), in a reanalysis of other studies, found a 20, 35, and 50 percent loss of coldwater habitat from the Rocky Mountains by 2025, 2050, and 2100, respectively.

In these studies, habitat loss is predicted to occur in the lower elevation stream reaches (or lower latitude streams) due to increased temperatures. As a result, salmonid populations will be restricted to increasingly higher elevations or to more northern latitudes (Meisner et al. 1988, p. 6; Regier and Meisner 1990, p. 11; Keleher and Rahel 1996, p. 2; Nakano et al. 1996, pp. 716, 717; Rahel et al. 1996, p. 1122; Poff et al. 2002, p. 7; Rieman et al. 2007, p. 1558). Consequently, coldwater species occupying the southern distributions of their ranges are seen as more susceptible to extirpation as a consequence of global climate change (Poff et al. 2002, p. 8; Rieman et al. 2007, pp. 1552, 1553). Rio Grande cutthroat trout are the southernmost subspecies of cutthroat trout (Behnke 2002, p. 143).

Rio Grande cutthroat trout primarily occupy high-elevation headwater tributaries. Dispersal to new habitats is unlikely because they currently occupy the uppermost available habitat. Warming of lower elevation stream segments may limit restoration opportunities in the future and provide a competitive advantage to brown, rainbow, and brook trout in locations where these nonnatives occur with Rio Grande cutthroat trout (De Staso and Rahel 1994, pp. 293, 294; Dunham et al. 2002, p. 380; Paroz 2005, p. vi; Bear et al. 2007, p. 1118; Shemai et al. 2007, p. 322).

The Santa Fe and Carson National Forests have monitored stream temperature data using thermographs (instruments that record temperature at designated intervals, e.g., once every 4 hours) (Eddy 2005, Martinez

2007). From 2001–2003, 47 thermograph stations were used to monitor 21 streams on the Santa Fe National Forest, representing 385 km (239 mi) of stream (Eddy 2005, p. 5). Seven of the 21 streams are currently occupied by Rio Grande cutthroat trout conservation populations; all 21 are believed to be historical habitat. Temperature data collected were compared with New Mexico Environment Department (NMED 2007) standards for high quality coldwater fisheries and with Santa Fe National Forest standards, which are slightly more stringent than NMED but are more in line with standards for coldwater fisheries in the western States (Table 3) (Eddy 2005, p. 4). “Properly functioning” indicates that the water temperature of the stream is within the optimal range for feeding, physiology, and behavior for coldwater fish. “At risk” indicates that the water temperature is slightly warmer than optimal, and “not properly functioning” indicates that the water temperature is too warm to support a healthy cold water fishery.

Table 3. Santa Fe National Forest and NMED water quality temperature standards for high quality coldwater fisheries.

Water Temperature Standards	Properly Functioning	At Risk	Not Properly Functioning
Santa Fe National Forest 7-Day Average Maximum	=17.8 °C (= 64 °F)	17.8-21.1 °C (64 to 70 °F)	>21.1 °C (>70 °F)
NMED 3-Day Average Maximum	<20 °C (<68 °F)	20 to <23 °C (68 to <73.4 °F)	=23 °C (=73.4 °F)

Using the Santa Fe National Forest standards, stream segments represented by 12 thermograph stations were properly functioning (67.3 km (41.8 mi)), stream segments represented by 20 stations were at risk (162.1 km (100.7 mi)), and stream segments represented by 15 stations were not properly functioning (154.7 km (96.1 mi)) (Eddy 2005, p. 5). Using NMED standards, stream segments represented by 23 stations (172.7 km (107.3 mi)) were properly functioning, stream segments represented by 12 stations (82.2 km (51.1 mi)) were at risk, and stream segments represented by 12 stations (129.1 km (80.2 mi)) were not properly functioning (Eddy 2005, p. 5). Only nine streams were properly functioning for their entire length, using both standards. Of these, only Cave Creek is occupied by a Rio Grande cutthroat trout conservation population (Eddy 2005, p. 5). The Pecos River and Rio de las Vacas are properly functioning in occupied Rio Grande cutthroat trout habitat but have at risk (Pecos River) or not properly functioning sections (Rio de las Vacas) below occupied habitat (Eddy 2005, pp. 34, 35, 92). Canones, Polvadera, and Rio Cebolla were the other streams monitored that have conservation populations of Rio Grande cutthroat trout. These streams were identified as at risk or not properly functioning (Rio Cebolla) in occupied habitat (Eddy 2005, pp. 9, 19, 26).

Monitoring on the Carson National Forest indicated that Comanche Creek had several periods in which temperature standards were exceeded (Martinez 2007, pp. 3-22). Eight sites on Comanche Creek were monitored in 1998, 1999, and 2004. Temperatures were highest in 1998 and 1999, years of lower runoff. Temperatures in 1998 were very high, with five of the eight sites recording temperatures from 26.6–29.5 °C (80–85 °F) (Martinez 2007, pp. 3-22). At the remaining three sites, temperatures reached 26.4 °C (79.5 °F). Thermographs went in on June 23 each year, and in 1998, maximum temperatures ranged from 22.9–24 °C (73.2–76 °F) at all eight sites on the first day the recorders were deployed, indicating that there were probably several days of warm temperatures that occurred before monitoring began (Martinez 2007, pp. 3-22). In total, of 14 streams occupied by Rio Grande cutthroat trout and monitored by thermographs on the Santa Fe and Carson National Forests, 8 streams were either at risk or not properly functioning because of high water temperature (Eddy 2005, pp. 8-116; Martinez 2007, pp. 3-22; NMED 2007, pp. 15-331). An additional conservation population in Colorado was also identified at risk from high water temperatures by Pritchard and Cowley (2006, p. 39). Because only a fraction of the streams occupied by Rio Grande cutthroat trout have been monitored, there are likely more that are at risk.

The thermograph data collected on the Santa Fe and Carson National Forests indicate that stream temperatures in several streams are already at risk or are considered “not properly functioning” for trout. Because air temperature and consequently water temperature are expected to increase with climate change, we would anticipate that more streams that are currently not properly functioning will become unsuitable for Rio Grande cutthroat trout, those currently at risk will enter the not properly functioning category, and more streams will fall into the at risk category for temperature. As a consequence, suitable habitat will decrease and fragmentation will increase.

In contrast to the potential negative impacts of water temperature increase on Rio Grande cutthroat trout, there could also be a potential benefit. Cold summer water temperatures (mean July temperature of less than 7.8 °C (46 °F)) have been found as a limiting factor to recruitment of cutthroat trout in high-elevation streams (Harig and Fausch 2002, p. 545; Coleman and Fausch 2007, pp. 1238-1240). Coleman and Fausch (2007, p. 1240) found that cold summer water temperatures in Colorado streams likely limited recruitment of cutthroat trout because of reduced survival of age-0 fish (fish less than 1 year old). Harig and Fausch (2002, p. 538) recorded summer water temperatures in 5 streams in New Mexico and 11 streams in Colorado from 1996 to 1999 (Harig and Fausch 2002, p. 540). None of the streams in New Mexico had July water temperatures below 7.8 °C (46 °F) (lowest July average was in the Pecos River, 9.2 °C (48.6 °F)). Three of four streams in Colorado that no longer had translocated fish present had summer averages below 7.8 °C (46 °F) (Harig and Fausch 2002, pp. 538, 539). The remaining eight streams in Colorado had summer averages greater than or equal to 8.3 °C (46.9 °F), indicating that cold summer water temperatures were most likely not limiting for these Rio Grande cutthroat trout populations (Harig and Fausch 2002, pp. 538, 539). Two of the four streams (Little Medano and Unknown Creek), which no longer had transplanted fish at the time of Harig and Fausch’s research (1996-1998), dried in 2002 (Alves et al. 2007, pp. 43, 44), raising the possibility that insufficient refugium may be limiting, not low summer water temperatures.

Cold summer water temperatures have been identified as limiting in one stream: Deep Canyon, Colorado (Pritchard and Cowley 2006, p. 42). However, Alves et al. (2007, p. 135) indicated that Deep Canyon has temperatures from 8 to 16 °C (46.4 to 60.8 °F) during spawning and incubation periods. Of the 14 Rio Grande cutthroat trout streams monitored with thermographs on the Santa Fe and Carson National Forests, 2 (Pecos and Mora Rivers) were found to have July temperatures less than 7.8 °C (46 °F) (data summarized from Eddy 2005, Martinez 2007). The result for the Pecos River contrasts with the data Harig and Fausch (2002, p. 540) collected (9.2 °C (48.6 °F)) and likely reflects a difference in thermograph placement or year (e.g., temperature variability, amount of runoff).

In summary, air temperatures in the range of Rio Grande cutthroat trout have already increased by approximately 1 °C (2.5 °F) over the last 30 years, warm water temperatures have already reached the likely limits of suitability in some Rio Grande cutthroat trout streams, and several others are at risk. Water temperatures are expected to increase in the future, affecting more streams and making lower elevation reaches either marginal or unsuitable. This is particularly true for populations that are located in New Mexico and are at the southernmost extent of the range but could also be true for smaller streams in Colorado. Although cold water temperatures are limiting to some high-elevation salmonid populations, cold water limitation has not been convincingly demonstrated for any Rio Grande cutthroat trout population. Therefore, we view the negative impact of stream warming to outweigh any benefit that may occur from increased water temperature.

The studies cited above that forecast coldwater habitat loss calculate the loss based on increases in temperature alone, assuming temperatures will rise above the thermal tolerance limits of coldwater species, thereby limiting the amount of suitable habitat available. The ancillary effects of increased temperature, such as increased habitat fragmentation (Rahel et al. 1996, pp. 1121, 1122; Rieman et al. 2007, pp. 1553, 1560, 1562), changes in invertebrate prey base (both species composition and availability) (Ries and Perry 1995, p. 204; O'Neal 2002, p. 4; IPCC 2002, p. 17; Harper and Peckarsky 2006, p. 618; Bradshaw and Holazpel 2008, p. 157), effects on spawning (Jager et al. 1999, p. 236), increased competitive interactions with nonnative trout (Meisner 1990b, p. 1068; De Staso and Rahel 1994, pp. 289, 294; O'Neal 2002, p. 33; Chu et al. 2005, p. 307; Sloat et al. 2005, p. 235; Rahel and Olden 2008, pp. 521-531), additional invasive species (IPCC 2002, p. 32), increased susceptibility to disease (Hari et al. 2006, p. 24), and effects on water quality (e.g., dissolved oxygen, nutrients, pH) (Meisner et al. 1988, p. 7), are not considered in calculating the potential habitat loss.

Of these factors, increased fragmentation, nonnative fish effects, and disease risk are considered of particular importance to Rio Grande cutthroat trout and are discussed in more detail.

Fragmentation. Climate change is predicted to increase fragmentation of coldwater fish habitat (Nakano et al. 1996, p. 719; Rahel et al. 1996, p. 1122; Rieman et al. 2007, p. 1553). Currently, 112 of 120 (93 percent) conservation populations of Rio Grande cutthroat trout exist as fragments, with no well-connected populations (Alves et al. 2007, p. 29). Only one population, Comanche Creek, has a moderate degree of connectivity (2010 database). As noted above, Comanche Creek currently has very high water temperatures (Martinez 2007, pp. 3-22), and several of the small tributaries of upper Comanche Creek dried in 2006 (Patten et al. 2007, p. 76). Consequently, the one moderately well-connected population may already be at risk. Seven Rio Grande cutthroat trout conservation populations are considered weakly networked (occupied habitat consists of two to three connected streams, possible infrequent straying of adults may occur) (Alves et al. 2007, p. 77). Of these seven, six have connecting stream segments less than 1.5 m (5 ft) in width (2010 database), and are therefore considered at risk from drying. Consequently, fragmentation of these weakly networked systems appears reasonably likely in the foreseeable future.

Nonnative Fish Interactions. Water temperature is a determining factor in the distribution of salmonids (Rahel and Hubert 1991, p. 326; Schrank et al. 2003, p. 100; Sloat et al. 2005, p. 225). Additionally, temperature regime is a key determinant of the outcome of competitive interactions in a fish community (MuCullough 1999, p. 156). Fish living within their optimum temperature range have improved performance relative to other species not within their optimum range (MuCullough 1999, p. 156). There is evidence that the reason cutthroat trout occupy headwater streams and rainbow, brook, and brown trout occupy downstream reaches is because of the influence of temperature on competitive abilities (Dunham et al. 2002, p. 380). DeStaso and Rahel (1994, pp. 293, 294) looked at competition between Colorado River cutthroat trout (Oncorhynchus clarki pleuriticus) and brook trout. They found that at warmer water temperatures (20 °C (68 °F)) brook trout was dominant, as evidenced by a higher level of interspecific aggression, more time spent at the optimal feeding position, and greater food consumption (DeStaso and Rahel 1994, pp. 293, 294). Brook trout also tolerated higher temperatures (DeStaso and Rahel 1994, p. 294).

As mentioned earlier, when brook trout co-occur with cutthroat trout, species interactions act to suppress cutthroat trout populations (Dunham et al. 2002, p. 378; Peterson et al. 2004, pp. 765-769; Young and Guenther-Gloss 2004, p. 193). Because brook trout tolerate higher temperatures, warmer stream temperatures would provide a competitive advantage to brook trout over Rio Grande cutthroat trout, exacerbating the problems that already exist for Rio Grande cutthroat trout populations.

In New Mexico, brown trout is the most common nonnative trout present in Rio Grande cutthroat trout conservation populations (summarized from 2010 database). Jager et al. (1999, p. 232) modeled the effects of an increase of 2 °C (3.6 °F) air temperature on brown trout distribution in the Sierra Nevada, California. They found that brown trout numbers would increase in upstream cooler reaches, and decrease downstream through starvation of juvenile and adult fish (Jager et al. 1999, p. 235). This is consistent with observations of trout in Switzerland. In Switzerland in 1987, after a long period of essentially stable river water temperatures, water temperatures took an abrupt and significant increase to a higher mean level, which was attributed to a corresponding increase in air temperature (Hari et al. 2006, pp. 10, 21). Suitable habitat for brown trout, a trout species native to the area, moved upstream, and downstream portions became unsuitable (Hari et al. 2006, pp. 10, 21).

McHugh and Budy (2005, p. 2791) hypothesized that cold incubation temperatures might explain why brown trout did not form self-sustaining populations at high elevations in Logan River, Utah, where upstream water temperatures were not too cold for adult brown trout. Because brown trout have a higher optimal growth temperature (between 13–18 °C (55.4–64.4 °F)) than cutthroat trout (12–13 °C (53.8–55.4 °F), and because cold incubation temperatures may currently be limiting brown trout range expansion upstream, it is anticipated that warmer water temperatures will make additional upstream habitat suitable for brown trout, reducing the area where Rio Grande cutthroat trout are now dominant.

When cutthroat trout co-occur with rainbow trout, cutthroat trout typically occupy the upper colder reaches and rainbow trout occupy the lower, warmer stream reaches (Sloat et al. 2005, p. 235; Robinson 2007, p. 80). As identified by Alves et al. (2007, p. 35), rainbow trout occupy the same stream reaches as four conservation populations of Rio Grande cutthroat trout. Rainbow trout have a higher thermal tolerance than do cutthroat trout (Bear et al. 2007, pp. 1115, 1116). Because rainbow trout are able to tolerate higher temperatures than Rio Grande cutthroat trout, we expect that warming stream temperatures will give rainbow trout a competitive advantage over Rio Grande cutthroat trout. Monitoring and maintenance of barriers will continue to be essential to prevent hybridization and competition.

White sucker are native to the middle elevations of the Pecos and Canadian river drainages in New Mexico, but it has been introduced widely throughout the State and is sympatric with at least two populations of Rio Grande cutthroat trout (Sublette et al. 1990, p. 199; 2010 database). White sucker have a preferred water temperature of 22.4–27.1 °C (72.3–80.8 °F) (Sublette et al. 1990, p. 198). Sublette et al. (1990, p.199) noted that white sucker are highly fecund (produce numerous offspring) and often dominates a body of water. Comanche Creek (elevation approximately 2,900 m (9,500 ft)) has an abundant white sucker population, most likely due to the warm water temperatures discussed above. In 2007, over 20,000 white sucker were removed from Comanche Creek during a Rio Grande cutthroat trout restoration project (Patten 2007). Before the restoration, fish biomass was dominated by white sucker, and an inverse relationship was found between Rio Grande cutthroat trout and white sucker density (Patten et al. 2007, pp. 17, 18). Because both white sucker and Rio Grande cutthroat trout feed on aquatic insects, there is the potential for high numbers of white sucker to negatively impact food availability for Rio Grande cutthroat trout. We would anticipate the warmer stream temperatures would lead to more stream habitat becoming suitable for white sucker with potential negative impacts on Rio Grande cutthroat trout populations.

Disease. As mentioned earlier (see the “Disease and Predation” section in Factor C above) it had been thought that Rio Grande cutthroat trout were provided some level of protection against whirling disease because tubificid worms are most abundant in warm, degraded habitats and Rio Grande cutthroat trout occur in high-elevation, coldwater streams. However, Nehring (2009, p. 7) found equal abundance of lineage III tubificid worms in elevations from 1,829 m (6,000 ft) to 3,657 m (12,000 ft). Thus, it is clear that elevation does not provide protection from exposure to the disease.

El-Matubouli et al. (1999, pp. 637, 638) found that temperatures from 10–15 ï‚°C (50–59 ï‚°F) were optimum for development and maturation of the parasite inside the tubificid worm. Blazer et al. (2003, p. 24) found that the greatest production of TAMs occurred at temperatures from 13–17 °C (55.4–62.6 °F). Although the effect of temperature on survival of the tubificid worms was not statistically detectable, DuBey et al. (2005, p. 341) found that survival was consistently higher at 17 ï‚°C (62.6 ï‚°F) than at 5 ï‚°C (41 ï‚°F). Schisler et al. (2000, p. 862) found that multiple stressors on rainbow trout, especially the combination of M. cerebralis infection and temperature, increased mortality drastically. At 12.5 ï‚°C (54.5 ï‚°F) mean mortality of rainbow trout exposed to M. cerebralis was 41.7 percent. Mean mortality of rainbow trout exposed to M. cerebralis and held at a temperature of 17 °C (62.6 ï‚°F) was 60 percent (Schisler 2000, p. 861). Water temperature often exceeds 17 ï‚°C (62.6 ï‚°F) in July and August in Rio Grande cutthroat trout streams that have been monitored (Eddy 2005, Martinez 2007).

Thompson et al. (1999, p. 318) found that as water temperature increased from May to July, rainbow and cutthroat trout infected with M. cerebralis suffered high rates of mortality even though they had survived well in the winter. In a field study of the effects of water temperature, discharge, substrate size, nutrient concentration, primary productivity, and relative abundance of T. tubifix, de la Hoz Franco and Budy (2004, p. 1183) found that prevalence of M. cerebralis in trout increased with water temperature. Across sites where cutthroat trout were present, the lowest prevalence of infection occurred in the headwaters where average daily water temperature was 9.2 ï‚°C (48.6 ï‚°F), whereas the highest levels of infection occurred at a low elevation site where the temperature was the highest (greater than12 ï‚°C (53.6 ï‚°F)) (de la Hoz Franco and Budy 2004, p. 1186).

While water temperature in some streams may warm to the point (greater than 20 ï‚°C (68 ï‚°F)) of inhibiting the production of TAMs (Blazer et al. 2003, p. 24), it is anticipated that the overall increases in water temperature will be favorable for T. tubifix and TAM production. From these studies we conclude that elevation does not provide protection to Rio Grande cutthroat trout populations and that increasing water temperature would increase the production of TAMs and the survival of tubificid worms (up to about 20 ï‚°C (68 ï‚°F)), and increased water temperature would increase mortality of infected Rio Grande cutthroat trout.

In summary, stream warming will most likely decrease the amount of suitable habitat available for Rio Grande cutthroat trout. Warmer stream temperatures may, in the foreseeable future, make currently occupied reaches of stream more stressful or unsuitable. Suitable habitat is likely to be reduced, primarily at the downstream end of stream reaches and in small tributaries, leading to increased fragmentation, shorter occupied segments, and increased risk of extirpation. Warmer water temperatures will allow nonnative fishes to expand their range and give them a competitive advantage over Rio Grande cutthroat trout. Stress from warm water temperatures increases susceptibility to and mortality from disease. Although whirling disease positive sites are currently still limited within the range of Rio Grande cutthroat trout, managers will need to continue to monitor the disease closely. Increased water temperatures would increase the threat posed by whirling disease.

Decreased Streamflow

Current models suggest a decrease in precipitation in the Southwest (Kundzewicz et al. 2007, p. 183; Seager et al. 2007, p. 1181), which would lead to reduced streamflows and a reduced amount of habitat for Rio Grande cutthroat trout. Streamflow is also predicted to decrease in the Southwest even if precipitation were to increase moderately (Nash and Gleick 1993, p. ix; NMOSE 2005, p. 6; Hoerling and Eischeid 2007, p. 35). Winter and spring warming causes an increased fraction of precipitation to fall as rain, resulting in reduced snowpack, earlier snowmelt, and decreased summer runoff (Christensen et al. 2004, p. 4; Stewart et al. 2005, p. 1137; Regonda et al. 2005, p. 373). Earlier snowmelt and warmer air temperatures lead to a longer dry season, which affects streamflow. Warmer air temperatures lead to increased evaporation, increased evapotranspiration, and decreased soil moisture. These three factors would lead to decreased streamflow even if precipitation increased moderately.

Although not studied as extensively as the Colorado River basin, a decrease in runoff of 5-10 percent for the Rio Grande basin (75 percent model agreement) has been projected by 2050 (Ray et al. 2008, p. 37). Discharge in the Jemez River, a tributary to the Rio Grande, has shown a steady decrease from 1987 to 2007 from approximately 95 cubic feet per second (cfs) to 50 cfs even though precipitation in the area has shown no change (Western Regional Climate Center 2011, p. 1). From 1987 to 2007, monthly average air temperature was 11.5 °C (52.8 °F) compared to the long term average (1914 to 1986) of 10.7 °C (51.3 °F)

(Western Regional Climate Center 2011, p. 1). These data indicate a significant decrease in discharge (nearly 50 percent) without a significant decrease in precipitation with a modest increase in air temperature in watersheds occupied by Rio Grande cutthroat trout.

Decreased streamflow causes streams to become smaller, thereby reducing the amount of habitat available for aquatic species (Lake 2000, p. 577). A smaller stream is affected more by air temperature than a larger one, exacerbating the effects of warm (and cold) air temperature (Smith and Lavis 1975, p. 229). Small headwater streams, such as those occupied by Rio Grande cutthroat trout, and intermittent streams may dry completely. Seventy-one percent of Rio Grande cutthroat trout streams are less than 8 km (5 mi) in length (Alves et al. 2007, p. 26). Because stream length is one indicator of population viability (Harig et al. 2000b, p. 997; Hilderbrand and Kershner 2000, p. 515; Young et al. 2005, p. 2405; Cowley 2007, p. 426), further shortening of Rio Grande cutthroat trout streams due to drying is expected to have a negative impact on populations.

Fourteen Rio Grande cutthroat trout streams with conservation populations became intermittent and had populations negatively impacted or lost because of the 2002 drought (Japhet et al. 2007, pp. 4244; Patten et al. 2007, pp. 14, 31, 32, 34, 39, 76). The number of streams affected was most likely even higher, because managers only survey a fraction of the 105 conservation populations in any given year. Approximately 27 conservation populations are in streams that are 1.5 m (5 ft) or less in width throughout their entire length (2010 database). An additional 29 stream segments of tributaries to the conservation populations are also less than 1.5 m (5 ft) in width (2010 database), which indicates that fragmentation of existing connected populations could increase. We recognize that not all streams less than 1.5 m (5 ft) wide have an equal probability of drying. Some are likely spring fed or are narrow and deep, thus decreasing the likelihood of drying. However, because of the high number of Rio Grande cutthroat trout streams less than 8 km (5 mi) in length (71 percent of conservation populations) and less than 1.5 m (5 ft) wide, the risk of drying is considered high.

Insight into the effects that climate change may have on headwater streams is provided by research done at the Experimental Lakes Area in northwestern Ontario (Schindler et al. 1996). The experimental area was set up in 1968, and precipitation, evaporation, air temperature, wind velocity, and other meteorological and hydrological parameters were monitored continuously throughout the 1970 to 1990 study period (Schindler et al. 1996, p. 1005). During that period, the area experienced gradual air temperature warming (1.6 °C (2.9 °F)) and decreased precipitation (as measured by a decline of over 50 percent in annual runoff) (Schindler et al. 1996, p. 1004). Whether these changes can be attributed to climate change or local variation is unknown, but they are consistent with changes that are predicted under global climate change scenarios. In the early 1970s, two streams in the area were perennial and one stream was dry for less than 10 days per year. By the late 1980s, all three streams were dry for 120–160 days during the summer (Schindler et al. 1996, p. 1006). Because northern latitude ecosystems mimic higher elevation systems in southern latitudes, the effects seen on these streams likely represent what may happen at high-elevation streams in New Mexico and Colorado, within the range of Rio Grande cutthroat trout.

In summary, stream drying has already had a negative impact on several Rio Grande cutthroat trout populations. Seventy-one percent of Rio Grande cutthroat trout conservation populations are in stream fragments 8 km (5 mi) or less in length, and many of the populations are in streams less than 1.5 m (5 ft) wide. Further, there is a high risk of stream drying as a result of climate change, leading to shorter stream segments and increased fragmentation. A rangewide emergency rescue and evacuation plan does not exist for Rio Grande cutthroat trout and would likely not be effective. If widespread drought were to occur, affecting many streams at the same time, it is unclear if sufficient facilities or donor streams exist to accept the rescued fish, or if the effort would take place according to a carefully conceived, well-organized plan.

Change in Hydrograph

Changes in air temperature and precipitation will likely lead to changes in the magnitude, frequency, timing, and duration of runoff (Poff et al. 2002, p. 4). Stewart et al. (2004, p. 1152) show that spring streamflow during the last 5 decades has shifted so that the major peak now arrives 1 to 4 weeks earlier, resulting in declining fractions of flow in the spring and summer. In Colorado, the onset of springflow has already shifted by 2 weeks (Ray et al. 2008, p. 2). The life history of salmonids is closely tied to flow regime, runoff in particular (Fausch et al. 2001, p. 1440). A change in timing or magnitude of floods can scour the streambed, destroy eggs, or displace recently emerged fry downstream (Erman et al. 1988, p. 2199; Montgomery et al. 1999, p. 378; Fausch et al. 2001, p. 1440). The environmental cues for Rio Grande cutthroat trout spawning are not known with certainty, but they are most likely tied to increasing water temperature, increasing day length, and possibly flow, as it has been noted that they spawn when runoff from snowmelt has peaked and is beginning to decrease (Behnke 2002, p. 141; Pritchard and Cowley 2006, p. 25). Consequently, a change in the timing of runoff from spring to winter could disrupt spawning cues because peak flow would occur when the days are still short in length and water temperatures cold.

Increased winter temperatures cause more precipitation to fall as rain instead of snow (Regonda et al. 2005, p. 373). Snow covering small streams provides valuable insulation that protects aquatic life (Needham and Jones 1959, p. 470; Gard 1963, p. 197). Gard (1963, p. 196) measured temperatures above, within, and below the snow at Sagehen Creek, California, a small Sierra Nevada mountain stream. He found that although there was a 35.4 °C (63.8 °F) diurnal air temperature variation, within the snow the temperature variation was only 1.3 °C (2.3 °F) and the water temperature in the stream below varied by only 0.3 °C (0.55 °F). Stream freezing, which is more likely absent insulating snow cover, has been suggested as the cause of the extirpation of one Rio Grande cutthroat trout population (Ferrell 2006, p. 11). Anchor ice (ice frozen on the stream bed) and frazil ice (ice crystals suspended in the water) can also have negative effects on trout (Needham and Jones 1959, p. 465). High-elevation streams are rarely visited in winter; consequently, it is difficult to document the extent to which freezing may affect populations. However, the combination of reduced streamflow and reduced snow pack could lead to an increased probability of stream freezing in small headwater Rio Grande cutthroat trout streams.

Earlier snowmelt, which leads to less flow in the spring and summer, could either benefit Rio Grande cutthroat trout or be detrimental. The benefit could come because the young-of-year would have a longer growing season before winter. However, as discussed above, a longer season of lower flows would lead to increased stream temperatures and increased probability of intermittency and drying.

In summary, it is difficult to project how changes in the hydrograph as a result of climate change will affect Rio Grande cutthroat trout populations. If growing season is increased, water temperatures remain suitable, and the stream does not dry, it could be beneficial to Rio Grande cutthroat trout. However, if spawning cues are disrupted or egg and fry success is reduced because of winter floods or unseasonal extreme floods, it would be detrimental to the species. In addition, stream freezing may reduce suitable overwinter habitat or reduce population size in susceptible streams.

Extreme Events

An increase in extreme events such as drought, fires, and floods is predicted to occur because of climate change (IPCC 2007, p. 15). It is anticipated that an increase in extreme events will most likely affect populations living at the edge of their physiological tolerances. The predicted increases in extreme temperature and precipitation events may lead to dramatic changes in the distribution of species or to their extirpation or extinction (Parmesan and Matthews 2006, p. 344).

Drought. The relatively short-term drought of the early 2000s had a negative impact on or extirpated 14 Rio Grande cutthroat trout populations in Colorado and New Mexico (Japhet et al. 2007, pp. 42-44; Patten et al. 2007, pp. 14-40). A fifteenth population is thought to have been extirpated in 2006 by complete freezing caused by low flow in the winter (Ferrell 2006, p. 11). As discussed above, in the “Decreased Streamflow” section, it is anticipated that a prolonged, intense drought would affect many Rio Grande cutthroat trout populations, in particular those less than less than 8 km (5 mi) long and 1.5 m (5 ft) wide because of their small size.

Most Rio Grande cutthroat trout populations are currently protected from downstream populations of nonnative trout by barriers. Downstream reaches are larger streams that historically could have provided refugia for populations threatened by stream drying. If Rio Grande cutthroat trout disperse downstream now, they are lost from the conservation population once they pass over the barrier, as they will not be able to pass back over the barrier in an upstream direction. In the future, downstream water temperatures may be too warm to be suitable for Rio Grande cutthroat trout. In addition to stream drying, there is a clear association between severe droughts and large fires in the Southwest (Swetnam and Baisan 1994, pp. 11, 24, 28), as discussed below.

Drought can also predispose forests to attack by bark beetles (Curculionidae: Scolytinae) (Breshears et al. 2005, p. 15147; Hebertson and Jenkins 2008, p. 282; Negron et al. 2009, p. 1353). Bark beetles are major disturbance agents of western North American forests, often affecting larger areas than fire does (Raffa et al. 2008, p. 502). Bark beetles have caused regional-scale mortality of overstory trees, rapidly altering ecosystem type, associated ecosystem properties, and land surface conditions (Breshears et al. 2005, pp. 15147, 15148). Warmer air temperatures exacerbate the effects of drought on trees (Adams et al. 2009, p. 7063). In recent years, the magnitude of beetle kill has increased and expanded into persistent infestations into habitats that previously had only rarely been affected, and into previously unexposed habitats (Raffa et al. 2008, p. 503). The bark beetles in three genera (Dendroctonus, Ips, and Scolytus) are all present in forests that have Rio Grande cutthroat trout streams (Raffa et al. 2008, p. 502). These species have killed thousands of acres of trees since 2005. It is anticipated that the effects of large-scale beetle kill would be similar to the effects of fire, with decreased shading of streams, increased erosion, increased runoff, and increased input of large woody debris to the stream.

Fire. Since the mid-1980s, wildfire frequency in western forests has nearly quadrupled compared to the average of the period 1970–1986. The total area burned is more than six and a half times the previous level (Westerling et al. 2006, p. 941). In addition, the average length of the fire season during 1987–2003 was 78 days longer compared to 1970–1986, and the average time between fire discovery and control increased from 7.5 days to 37.1 days for the same time frames (Westerling et al. 2006, p. 941). McKenzie et al. (2004, p. 893) suggested, based on models, that the length of the fire season will likely increase further and that fires in the western United States will be more frequent and more severe. In particular, they found that fire in New Mexico appears to be acutely sensitive to summer climate and temperature changes and may respond dramatically to climate warming.

Changes in relative humidity, especially drying over the western United States, are also projected to increase the number of days of high fire danger (Brown et al. 2004, p. 365). High-elevation, subalpine forests in the Rocky Mountains typically experience infrequent (i.e., one to many centuries), high severity crown fires (Schoennagel et al. 2004, p. 664). These fires usually occur in association with extremely dry regional climate patterns (Swetnam and Baisan 1994, p. 28; Schoennagel et al. 2004, p. 664). Short drying periods do not create the conditions appropriate for fire in these typically cool, humid forests. Schoennagel et al. (2004, pp. 665, 666) concluded that recent increases in the area burned in subalpine forests are not attributable to fire suppression, but variation in climate exerts the largest influence on the size, timing, and severity of the fires. In contrast, low-elevation, ponderosa pine forests in the Rocky Mountains were historically characterized by frequent, low-severity fires (Schoennagel et al. 2004, p. 669). Fire suppression has significantly increased ladder fuels (fuels that allow fire to climb from the forest floor to the tops of trees) and tree densities, leading to unprecedented high-severity fires in these ecosystems (Schoennagel et al. 2004, p. 669). Rio Grande cutthroat trout streams occur in both forest types.

As discussed in the “Fire” section in Factor A above, because of the observed and predicted increase in fire season length, the predicted increase in frequency and severity of fires, the observation that fuel treatment is only effective in low-elevation, ponderosa pine forests, the expectation of an increase in the frequency of hot extremes, heat waves, and heavy precipitation (IPCC 2007, p. 15), and the fact that most Rio Grande cutthroat trout streams occur within a forested landscape, we conclude that wildfire associated with climate change will exacerbate habitat loss to Rio Grande cutthroat trout populations across their range.

Floods. The life history of salmonids is tied to the timing of floods (Fausch et al. 2001, p. 1440). A change in timing or magnitude of floods can scour the streambed, destroy eggs, or displace recently emerged fry downstream (Erman et al. 1988, p. 2199; Montgomery et al. 1999, p. 378; Fausch et al. 2001, p. 1440). Floods that occur after intense wildfires that have denuded the watershed are also a threat. As described in the "Fire" section in Factor A above, several streams in the Southwest have had populations of trout extirpated as a result of ash flows which occurred after fire (Rinne 1996, p. 654; Brown et al. 2001, p. 142; Patten et al. 2007, p. 33). Consequently, an increase in rain or snow events, intense precipitation that is unseasonable, or precipitation that occurs after fire could extirpate affected Rio Grande cutthroat trout populations.

In summary, extreme events, especially widespread fire and drought, will likely affect Rio Grande cutthroat trout populations in the foreseeable future through population extirpation, extreme population reduction, or habitat reduction. Several Rio Grande cutthroat trout populations have already been affected by drought. Fire has thus far primarily affected streams occupied by nonnative trout within the range of Rio Grande cutthroat trout, but there is no safeguard for Rio Grande cutthroat trout streams. The effect of a change in the timing of runoff may be significant but is more difficult to predict.

Climate Change Summary

The extent to which climate change will affect Rio Grande cutthroat trout is not known with certainty at this time. However, projections point to a rangewide negative impact through increased water temperatures, decreased streamflow, change in hydrograph, and an increased occurrence of extreme events. The combination of climate change stressors on a subspecies that occupies the southernmost range of the species that has already experienced a significant decrease in occupied stream miles and currently faces many known threats presents a tenuous future for this fish. According to Gleick (2000, pp. 62, 63), it is likely that ecosystems most vulnerable to climate change are those that are already near important thresholds where competition is occurring, where summer water temperatures are near the limit of concern, or where climate change will act in concert with other stressors. Ecosystems where Rio Grande cutthroat trout occur fit this description. Even though aquatic ecosystems have historically experienced temperatures similar to those projected, the projected rate of change falls outside the natural range of variation, and is therefore unprecedented (Poff et al. 2002, p. 3). The current extent of habitat fragmentation is also unprecedented, making adjustment through dispersal unlikely (Poff et al. 2002, p. 3). Therefore, although the extent that the global climate will modify Rio Grande cutthroat trout habitat in the future is not known with certainty, based on the current status of the species, the changes to its habitat that have already been observed, and the changes that are anticipated to occur in the foreseeable future based on the best available science, climate change is an additional threat to the persistence of Rio Grande cutthroat trout.

Fisheries Management

Hatcheries

Future management of Rio Grande cutthroat trout will depend in part on the use of hatchery-reared fish. Although hatcheries can produce many fish in a short period of time, the use of hatchery fish is not without risks (Busack and Currens 1995, pp. 73-78). Two recent papers have explored the risks of captive propagation used to supplement species that are declining in the wild (Araki et al. 2007, Frankham 2007). Araki et al. (2007, p. 102) found that there was approximately a 40 percent decline in reproductive capabilities per captive-reared generation when rainbow trout were moved to natural environments. Frankham (2007, p. 2) notes that characteristics selected for under captive breeding conditions are overwhelmingly disadvantageous in the natural environment. Minimizing the number of generations in captivity or making the captive environment similar to the wild environment are effective means for minimizing genetic adaptation to captivity (Frankham 2007, pp. 4, 5).

The history of broodstock management in New Mexico has been marked by many challenges (Cowley and Pritchard 2003, pp. 12, 13). The most recent challenges came from whirling disease infection at Seven

Springs Hatchery and the discovery that the broodstock were introgressed with Yellowstone cutthroat trout (Patten et al. 2007, p. 42). The hatchery was refurbished to eliminate M. cerebralis and the broodstock program was restarted in 2005 (Patten et al. 2007, p. 42). A recently revised broodstock management plan was completed for New Mexico (Cowley and Pritchard 2003).

Although the intent of fisheries management is positive, fisheries management may result in unanticipated outcomes. For example, Costilla Creek restoration efforts were unfortunately marred by the introduction of rainbow trout into the recently reclaimed stream (Patten et al. 2007, p. 101, Appendices VIII-X). The rainbow trout came from Seven Springs Hatchery, even though this hatchery is a designated as a Rio Grande cutthroat trout facility (NMDGF 2002, p. 28; Patten et al. 2007, p. 379). It is unclear why Seven Springs Hatchery was holding rainbow trout. Through a coordinated effort, managers believe they captured most, if not all, of the rainbow trout that were stocked into Costilla Creek along with Rio Grande cutthroat trout (Patten et al. 2007, pp. 18, 102). While electrofishing to recover the rainbow trout, two brook trout were also caught, indicating that the lower barrier was compromised, not all the fish were killed during treatment, or that an angler had released the fish above the barrier. In addition, because the stocked Rio Grande cutthroat trout came from Seven Springs Hatchery before the introgression with Yellowstone cutthroat trout was discovered, the Rio Grande cutthroat trout that were stocked were slightly introgressed (Patten et al. 2007, p. 102). For these reasons, relying on hatchery-reared Rio Grande cutthroat trout does not provide certainty that repatriation will be successful.

Summary of Factor E

Nonnative trout co-occur with 38 percent of Rio Grande cutthroat trout conservation populations. Because of the documented negative impacts of nonnative trout on cutthroat trout discussed above, nonnatives are an ongoing threat to the security of Rio Grande cutthroat trout. Fisheries management is integral to the conservation of Rio Grande cutthroat trout. Although there are some risks associated with fisheries management, the benefits outweigh the risks. Based on the best scientific and commercial information available, we conclude that climate change is a threat to Rio Grande cutthroat trout. Continued management actions to connect fragmented populations are essential. However, at this time, it is not clear that management actions can outpace some of the projected effects of climate change.

Conservation Measures Planned or Implemented :

Fisheries managers have worked very hard in the last several years to monitor populations, check and maintain barriers, test the genetic purity of populations, test streams for whirling disease, fund research, and reintroduce populations into appropriate streams (Japhet et al. 2007, pp. 22-27; Patten et al. 2007, pp. 4-19). New populations have been established in Costilla, South Ponil, Leandro, and Capulin Creeks in New Mexico, and in Big Springs, East Costilla, and West Costilla Creeks in Colorado. Populations were reestablished in Cat Creek and Little Medano Creek, Colorado, after being lost to the drought (Japhet et al. 2007, pp. 42-44). In addition, major restoration projections have gone through environmental review and are in progress on Placer, Comanche, and Costilla Creeks. Completion of these projects will contribute to the long-term persistence of Rio Grande cutthroat trout. The Forest Service, BLM, and National Park Service have been active partners in project implementation and have completed many miles of detailed stream surveys, which adds greatly to our knowledge of habitat condition.

New Mexico Tribes and Pueblos have recently taken initiatives to restore Rio Grande cutthroat trout on Tribal lands. The Mescalero Apache Tribe began inventorying their streams to determine presence and has reopened the Mescalero Tribal Fish Hatchery. The Tribe hopes to establish a Rio Grande cutthroat trout broodstock and raise Rio Grande cutthroat trout to support native fish restoration projects on Tribal lands. Santa Clara Pueblo received a Tribal Wildlife grant for nearly $200,000 for Rio Grande cutthroat trout restoration. The Pueblo is in the initial phases of project planning for restoring the Santa Clara Creek watershed and is pursuing a Candidate Conservation Agreement with Assurances with the Service. Nambe

Pueblo has also expressed an interest in Rio Grande cutthroat trout restoration and is working in collaboration with the Service, Forest Service, Southwest Tribal Fisheries Commission, and NMDGF to formulate a restoration plan to restore Rio Grande cutthroat trout in the Nambe River watershed. The Jicarilla Apache Nation has also been involved in Rio Grande cutthroat trout restoration and plans to expand their restoration efforts to additional creeks on the reservation in the near future. The Southwest Tribal Fisheries Commission, an organization composed of southwestern Native American Tribes, has developed a Memorandum of Understanding with NMDGF to acquire Rio Grande cutthroat trout eggs for juvenile and adult production in support of tribal Rio Grande cutthroat trout restoration projects. Currently, the Memorandum is still awaiting approval by both participants. If successful, these actions would provide further conservation for Rio Grande cutthroat trout.

Habitat fragmentation is a threat that can be partially alleviated by management activities. Three major watershed-scale projects have been initiated on private and Forest Service lands, and are in various phases of implementation. A joint project between Vermejo Park Ranch and the states of Colorado and New Mexico to restore the Costilla Creek watershed began in 2002 (Patten et al. 2007, pp. 95-102). The restoration removed brook trout, brown trout, and introgressed cutthroat trout and reintroduced Rio Grande cutthroat trout into Costilla Creek, 2 tributaries, and 3 small lakes, totaling 22 km (13.6 miles) of stream and 9.5 ha (23.5 ac) of lake (project is discussed further in the “Fisheries Management” section above). As part of the larger Costilla Project, 34 km (21.1 mi) of Comanche Creek and selected tributaries were chemically treated with piscicides (chemicals that kill fish) in 2007 and again in 2008. A draft Candidate Conservation Agreement with Assurances with private landowners has been drafted so that the Costilla Creek project can be extended downstream. Successful implementation of this project would lead to the restoration of approximately 241 km (150 mi) and 25 lakes (Patten and Sloane 2007, p. 7). The Placer watershed in Colorado also underwent chemical treatment in 2007 and was retreated in 2009. This watershed has the potential for approximately 80.5 km (50 mi) of connected stream. If successful, the Costilla-Comanche and Placer watersheds would represent substantial gains in the goal of creating connected stream systems for Rio Grande cutthroat trout.

While watershed restoration can reconnect streams and is the best method for addressing fragmentation, major restoration projects face many challenges including negative public sentiment towards using piscicides in streams which slows or stops projects (Patten et al. 2007, p. 102), incomplete treatment which leaves nonnatives present, sabotage of the treatment area (unauthorized introduction of nonnative trout) (Japhet et al. 2007, p. 17), subsequent barrier failure which allows nonnatives to reinvade a system (Japhet et al. 2007, p. 15), and inadvertent mistakes. While many stream segments have been restored and the Costilla and Placer watershed projects are in progress, no major watershed restorations have been completed.

Management agencies are actively working towards improving habitat conditions for Rio Grande cutthroat trout. On Forest Service lands, several projects have been completed recently to address habitat degradation caused by roads. For example, grant money was obtained and used to inventory and identify 97 road improvement projects to reduce sediment input into Comanche Creek (Martinez 2006, p. 5). Six culverts were installed or realigned and 10 sediment traps and energy dissipaters were installed below culvert spillways. Culverts that drained directly into Comanche Creek were removed. Abandoned logging roads were stabilized and unneeded roads were recontoured to natural slope and revegetated (Forest Service 2006, pp.18-19). In 2006, on the Santa Fe National Forest, over 1,829 m (6,000 ft) of buck and pole fence was constructed to improve traffic control and enforce an off-road vehicle closure around Rio Cebolla. Approximately 17.7 km (11 mi) of stream and riparian habitat was protected by this project (Forest Service 2006, p. 12). On the Rio Grande National Forest, road-stream crossing inventories and assessments were conducted for all streams with conservation populations to determine if the culverts were barriers to fish (Forest Service 2006, p. 4). Most of the 120 conservation populations (90 percent) have one or more restoration, conservation, or management activities either completed or currently being implemented (Alves et al. 2007, p. 60).

Since 2002, NMDGF and CDOW visited approximately 40 and 50 Rio Grande cutthroat trout conservation populations, respectively, to assess barrier presence and condition. Seven new barriers have been installed since 2002, and maintenance was done on at least eight (Japhet et al. 2007, pp. 24, 25; Patten et al. 2007, pp. 6, 11, 12, 16, 17, 53). Both agencies have also mechanically and chemically removed nonnative trout from Rio Grande cutthroat trout streams. NMDGF removed nonnatives from 11 streams, and CDOW removed them from 2 (Japhet et al. 2007, p. 26; Patten and Sloane 2007, p. 5).

The CDOW and NMDGF tested Rio Grande cutthroat trout populations for genetic purity using the best available technologies. In many instances, the results confirmed previous assessments of genetic purity, while in other cases populations were either upgraded or downgraded (Japhet et al. 2007, pp. 46-47; Patten et al. 2007, pp. 43-45). Diagnostic markers for Yellowstone cutthroat trout were also identified, which has led to more refined testing and more confidence in the categorization of the populations. The most recent results were used in the 2010 database. Results of the testing can be found in peer-reviewed literature (e.g., Pritchard et al. 2007a, pp. 1311-1329; Pritchard et al. 2007b, pp. 606-623) and in reports to the States (e.g., Pritchard and Cowley 2005, pp. 1-75).

The Santa Fe National Forest has been very proactive about public education. They estimate that up through 2006 their “Respect the Rio” program directly reached over 9,300 people (Ferrell 2006, p. 16). They developed the Rio Grande Cutthroat Trout Life Cycle Game, which has traveled to classrooms, Earth Day events, and Kids’ Fishing Day celebrations (Ferrell 2006, p. 15). The game has also been translated into Spanish to reach students who speak English as a second language. It is estimated that over 1,000 children and adults have played the game.

The States of Colorado and New Mexico jointly host an annual meeting of the Rio Grande Conservation Team, which consists of Federal and State agency personnel, researchers, representatives of Tribes and private landowners, and Trout Unlimited, among others. This group coordinates restoration efforts and shares information and research. They are currently drafting a Conservation Strategy that would design and implement measures necessary to recover the species.

In New Mexico, a Rio Grande Cutthroat Trout Working Group meets semiannually to discuss Rio Grande cutthroat trout conservation, projects, and volunteer opportunities and to coordinate and communicate efforts among the participants. Regular members are NMDGF, the Service, Trout Unlimited, New Mexico Trout, and the Forest Service. The members are committed to Rio Grande cutthroat trout conservation.

Summary of Threats :

The historical range of Rio Grande cutthroat trout has been reduced by at least 90 percent over the last 150 years because of water diversions, stream drying, dams, habitat degradation, changes in hydrology, hybridization with rainbow trout, or competition with brown and brook trout. Their habitat has become increasingly fragmented to the point that 93 percent of the conservation populations, representing 80 percent of occupied miles, are in isolated, high-elevation stream segments. Fragmentation and isolation prevent gene flow among populations and increase extinction risk from demographic and stochastic events. Seventy-one percent of Rio Grande cutthroat trout conservation populations occupy stream segments of 8.1 km (5 mi) or less which limits the habitat available and consequently population numbers for a majority of populations. Shorter stream lengths also have limited refugia, which are important for high-elevation populations and populations that face environmental stressors such as drought (intermittency), flooding, and increased water temperatures.

Approximately 38 percent of Rio Grande cutthroat trout conservation populations co-occur with nonnative trout. Competition, predation, and hybridization with nonnative trout are considered an important source of stress that can depress Rio Grande cutthroat trout population numbers or replace them. Habitat condition and whirling disease are threats to particular populations. It is unknown the extent to which habitat (pool habitat in particular) is limiting, although it is apparent it is a problem in some streams. Whirling disease is present within the range of Rio Grande cutthroat trout. Although a major threat once a population is infected, whirling disease is currently spreading very slowly and only one conservation population has been infected. The infected stream is being restored.

Climate change is occurring and is affecting the landscape and the habitat occupied by Rio Grande cutthroat trout. Warming trends in the Southwest exceed global averages by about 50 percent, moderate increases in precipitation are unlikely to offset the negative impacts to the water supply caused by increased temperature, and temperature increases in the Southwest are predicted to continue to be greater than the global average. There has already been a documented rise in air temperature in landscapes occupied by Rio Grande cutthroat trout and spring runoff is occurring 1 (New Mexico) to 2 (Colorado) weeks earlier than historically. It is anticipated that the intensity, frequency, and duration of extreme events (e.g., drought, flooding) will increase as a consequence of climate change. Drought is expected to have negative consequences on the amount and quality of habitat available to Rio Grande cutthroat trout.

Increased air temperature will lead to stream warming and will likely decrease the amount of suitable habitat available for Rio Grande cutthroat trout. Stream temperatures in several streams are already unacceptably high for coldwater fish. Warmer stream temperatures may, in the foreseeable future, make currently occupied reaches of stream more stressful or unsuitable. Suitable habitat is likely to be reduced, leading to increased fragmentation, shorter occupied segments, and increased risk of extirpation. Warmer water temperatures will allow nonnative fishes to expand their range and give them a competitive advantage over Rio Grande cutthroat trout. Stress from warm water temperatures increases susceptibility to and mortality from disease. Although whirling disease positive sites are currently still limited within the range of Rio Grande cutthroat, increased water temperatures would increase the threat posed by whirling disease.

Increased air temperature is expected to lead to decreased streamflow even if precipitation were to increase. There is evidence that streamflow has already decreased in the Jemez River in spite of stable precipitation. Decreased streamflow would lead to more stream intermittency and stream drying, reducing the amount of habitat available to Rio Grande cutthroat trout and increasing stress levels. The occurrence of drought is expected to increase. Not only will drought affect streamflow directly, but it is anticipated that the magnitude and intensity of forest fires would increase. High severity fires and subsequent ash flows have eliminated trout populations in the Southwest. It is anticipated that the number of streams affected by fire will increase. Drought also increases the incidence of beetle attack on forest trees and can lead to widespread loss of forest cover. Although soil disturbance is not expected to be as great from a defoliated forest as from a forest fire, there would still be a loss of stream shading leading to increased water temperature and increased soil erosion in the short term.

Although the extent that climate change will modify Rio Grande cutthroat trout habitat in the future is not known with certainty, based on the current status of the species, the changes to its habitat that have already been observed, and the changes that are anticipated to occur in the foreseeable future based on the best available science, climate change is an additional threat to the persistence of Rio Grande cutthroat trout. No regulatory mechanisms are in place to address climate change.

We find that the Rio Grande cutthroat trout is warranted for listing throughout all of its range, and, therefore, find that it is unnecessary to analyze whether it is threatened or endangered in a significant portion of its range.

For species that are being removed from candidate status:

_____ Is the removal based in whole or in part on one or more individual conservation efforts that you determined met the standards in the Policy for Evaluation of Conservation Efforts When Making Listing Decisions(PECE)?

Recommended Conservation Measures :

• Develop a rangewide hatchery and genetics management plan
• Develop a rangewide rescue and evacuation plan
• Continue to create connected stream networks
• In occupied streams with less than 9.6 km (6 mi) of occupied habitat, expand protected habitat downstream or upstream
• Begin long-term, year-round monitoring of stream temperature and discharge
• Select a range of streams for long-term monitoring of year-class success and recruitment
• Continue to remove nonnative trout from occupied conservation populations
• Conduct quantitative habitat surveys to better document habitat condition rangewide

Priority Table

<table>
<tr><td>Magnitude</td><td>Immediacy</td><td>Taxonomy</td><td>Priority</td></tr>
<tr><td rowspan="6">High</td><td rowspan="3">Imminent</td><td>Monotypic genus</td><td>1</td></tr>
<tr><td>Species</td><td>2</td></tr>
<tr><td>Subspecies/Population</td><td>3</td></tr>
<tr><td rowspan="3">Non-imminent</td><td>Monotypic genus</td><td>4</td></tr>
<tr><td>Species</td><td>5</td></tr>
<tr><td>Subspecies/Population</td><td>6</td></tr>
<tr><td rowspan="6">Moderate to Low</td><td rowspan="3">Imminent</td><td>Monotypic genus</td><td>7</td></tr>
<tr><td>Species</td><td>8</td></tr>
<tr><td>Subspecies/Population</td><td>9</td></tr>
<tr><td rowspan="3">Non-Imminent</td><td>Monotype genus</td><td>10</td></tr>
<tr><td>Species</td><td>11</td></tr>
<tr><td>Subspecies/Population</td><td>12</td></tr>
</table>

Rationale for Change in Listing Priority Number:

Magnitude:

The threats to Rio Grande cutthroat trout occur rangewide but are judged to be moderate to low because there is good distribution and a comparatively large number of populations across the landscape. Approximately 10 percent of the conservation populations have more than 2,500 individuals and occur in stream lengths greater than 9.6 km (6 mi) with few threats present (i.e., no nonnative trout, no disease). There are additional populations with more than 2,500 fish in shorter stream segments that we expect will persist in the short-term and have the potential to be expanded. Nonnative trout are a permanent threat when they co-occur with Rio Grande cutthroat trout (38 percent of conservation populations), but management actions are taken to control nonnative trout numbers. Climate change is expected to affect all populations across the landscape to varying degrees, and is expected to be a permanent threat in the foreseeable future.

Imminence :

An increase in average mean air temperature of just over 1 °C (1.8 °F) in Arizona and just under 1 °C (1.8 °F) in New Mexico since 1976 (Parmesan and Galbraith 2004, pp. 18, 19; NMOSE 2006, p. 5; Lenart et al.

2007, p. 4) suggest that climate change is already occurring in the Southwest. Coldwater species like Rio Grande cutthroat trout are expected to be among the most sensitive species to climate change. Water temperatures in some Rio Grande cutthroat trout streams are already elevated beyond recommended temperatures for coldwater trout. At least 14 Rio Grande cutthroat trout streams either dried up or had populations negatively affected by the 2002 drought. Rio Grande cutthroat trout populations face multiple ongoing stresses such as nonnative trout, fragmented habitat, and limited habitat. The additional effects of climate change are expected to cause population extirpations and population bottlenecks. Consequently, threats to this species are considered imminent.

__Yes__ Have you promptly reviewed all of the information received regarding the species for the purpose of determination whether emergency listing is needed?

Emergency Listing Review

__No__ Is Emergency Listing Warranted?

The populations occur in multiple watersheds, and the threats acting on the subspecies are not occurring uniformly throughout its range, thus not all populations are likely to be impacted simultaneously by any of the known threats. Additionally, the existence of conservation agreements have resulted in the implementation of actions to improve the status of the subspecies and reduce the severity of threats.

Description of Monitoring:

NMDGF and CDOW monitor several Rio Grande cutthroat streams every year. When funding is available, Forest Service, and BLM also conduct stream surveys on their lands. Surveys are also conducted intermittently on Tribal lands. A rangewide database is updated annually based on surveys and work conducted in the prior field season, and includes all streams occupied by Rio Grande cutthroat trout, miles occupied, genetic purity, presence of nonnative fish, barrier type and condition, conservation actions that have been taken, land use activities, population estimates, and habitat characteristics. For this review, the Service met with biologists from NMDGF, CDOW, Forest Service, BLM, and Jicarilla Apache Nation. We also reviewed a spreadsheet created by the Rangewide Conservation Team that documented actions conducted on Rio Grande cutthroat trout streams in 2009. The data obtained from these sources represents the best information available on the status of the subspecies.

Indicate which State(s) (within the range of the species) provided information or comments on the species or latest species assessment:

Colorado,New Mexico

Indicate which State(s) did not provide any information or comment:

none

State Coordination:

Literature Cited:

Adams, H. D., M. Guardiola-Claramontea, G. A. Barron-Gafford, J. C. Villegas, D. D. Breshears. C. B. Zou, P. A. Troch, and T. E. Huxman. 2009. Temperature sensitivity of drought-induced tree mortality portends increased regional die-off under global change-type drought. Proceedings of the National Academy of Science 106:7063–7066.

Allen, C. D., and D. D. Breshears. 1998. Drought-induced shift of a forest-woodland ecotone: Rapid landscape response to climate variation. Proceedings of the National Academy of Science 95:14839–14842.

Allendorf, F. W., R. F. Leary, N. P. Hitt, K. L. Knudsen, L. L. Lundquist, and P. Spruell. 2004. Intercrosses and the U.S. Endangered Species Act: Should hybridized populations be included as Westslope cutthroat trout? Conservation Biology 18:1203–1213.

Alves, J. E. 2007. Clarifying information in the status review. Email to the U.S. Fish and Wildlife Service, December 7, 2007,Fisheries Biologist, Colorado Division of Wildlife, Monte Vista, Colorado.

Alves, J. E., T. Nessler, and D. Krieger. 2002. Rio Grande cutthroat trout status review for Colorado. Appendix III. Rio Grande cutthroat trout population status. Pages 40-43. Colorado Division of Wildlife, Monte Vista, Colorado.

Alves, J. E., K. A. Patten, D. E. Brauch, and P. M. Jones. 2007. Range-wide status of Rio Grande cutthroat trout (Oncorhynchus clarki viginalis): 2007. Report and Access data base. Submitted to the U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

Araki, H., B. Cooper, and M. S. Blouin. 2007. Genetic effects of captive breeding cause a rapid, cumulative fitness decline in the wild. Science 318:100–103.

Archer, S. R., and K. I. Predick. 2008. Climate change and ecosystems of the Southwestern United States. Rangelands June:23–28. http://www.ag.arizona.edu/research/archer/reprints/Archer_Predick_Rangelands08.pdf. Accessed April 12, 2011.

Backer, D. M., S. E. Jensen, and G. R. McPherson. 2004. Impacts of fire-suppression activities on natural communities. Conservation Biology 18:937–946.

Barnett, T. P., D. W. Pierce, H. G. Hidalgo, C. Bonfils, B. D. Santer, T. Das, G. Bala, A. W. Wood, T. Nozawa, A. A. Mirin, D. R. Cayan, and M. D. Dettinger. 2008. Human-induced changes in the hydrology of the Western United States. Science 319:1080–1083.

Bear, E. A., T. E. McMahon, and A. V. Zale. 2007. Comparative thermal requirements of westslope cutthroat trout and rainbow trout: Implications for species interactions and development of thermal protection standards. Transactions of the American Fisheries Society 136:1113–1121.

Behnke, R. J. 1967. Rare and endangered species: The Rio Grande trout (Salmo clarkii viginalis). Colorado Cooperative Fishery Unit, Colorado State University, Ft. Collins, Colorado.

Behnke, R. J. 2002. Trout and Salmon of North America. The Free Press. New York, New York.

Benjamin, J. R., J. B. Dunham, and M. R. Dare. 2007. Invasion by nonnative brook trout in Panther Creek, Idaho: Roles of local habitat quality, biotic resistance, and connectivity to source habitats. Transactions of the American Fisheries Society 136:875–888.

Bjornn, T. C. and J. Mallett. 1964. Movements of planted and wild trout in as Idaho river system. Transactions of the American Fisheries Society 93:70–76.

Blazer, V. S., T. B. Waldrop, W. B. Schill, C. L. Densmore, and D. Smith. 2003. Effects of water temperature and substrate type on spore production and release in eastern Tubifix tubifix worms infected with Myxobolus cerebralis. Journal of Parasitology 89:21–26.

Bradshaw, W. E., and C. M. Holzapel. 2008. Genetic response to rapid climate change: It’s seasonal timing that matters. Molecular Ecology 17:157–166.

Breshears, D. D., N. S. Cobb, P. M. Rich, K. P. Price, C. D. Allen, R. G. Balice, W. H. Romme, J. H. Kastens, M. L. Floyd, J. Belnap, J. J. Anderson, O. B. Myers, and C. W. Meyer. 2005. Regional vegetation die-off in response to global-change-type drought. Proceedings of the National Academy of Science 102:15144–15148.

Brooks, J. 2004. Emergency evacuation procedures for Gila Trout. U.S. Fish and Wildlife Service, New Mexico Fishery Resources Office, Albuquerque, New Mexico.

Brown, D. K., A. A. Echelle, D. L. Propst, J. E. Brooks, and W. L. Fisher. 2001. Catastrophic wildfire and number of populations as factors influencing risk of extinction for Gila Trout (Oncorhynchus gilae). Western North American Naturalist 61:139–148.

Brown, T. J., B. L. Hall, and A. L. Westerling. 2004. The impact of twenty-first century climate change on wildland fire danger in the western United States: an applications perspective. Climatic Change 62:365–388.

Buhl, K. J., and S. J Hamilton. 2000. Acute toxicity of fire-control chemicals, nitrogenous chemicals, and surfactants to rainbow trout. Transactions of the American Fisheries Society 129:408–418.

Burkey, T. V. 1995. Extinction rates in archipelagoes: Implications for populations in fragmented habitats. Conservation Biology 9:527–541.

Busack, C. A., and K. P. Currens. 1995. Genetic risks and hazards in hatchery operations: Fundamental concepts and issues. American Fisheries Society Symposium 15:71–80.

Calamusso, B., and J. N. Rinne. 1999. Native montane fishes of the Middle Rio Grande ecosystem: status, threats, and conservation. Pages 231-237 in D. M. Finch, J. C. Whitney, F. Jeffery, and S.R. Loftin, editors. Toward a sustainable future for the Middle Rio Grande Basin. RMRS-P-7. U.S. Forest Service, Rocky Mountain Research Station. Ogden, Utah. http://www.fs.fed.us/rm/pubs/rmrs_p007.pdf. Accessed April 12, 2011.

Carpenter, S. R., S. G. Fisher, N. B. Grimm, and J. F. Kitchell. 1992. Global change and freshwater ecosystems. Annual Review of Ecology and Systematics 23:119–139.

CDOW (Colorado Division of Wildlife). 2004. Conservation plan for Rio Grande cutthroat trout (Onchorhynchus clarki virginalis) in Colorado. Colorado Division of Wildlife, Denver, CO. 75 pp.

Christensen, J. H., et al.. 2007. Regional Climate Projections. Pages 848–940 in Climate Change 2007: The Physical Science Basis. Chapter 11. Contribution of Working Group 1 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller, editors. Cambridge University Press, Cambridge, United Kingdom. http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter11.pdf. Accessed November 2, 2010.

Christensen, N. S., A. W. Wood, N. Voisin, D. P. Lettenmaier, and R. N. Palmer. 2004. The effects of climate change on the hydrology and water resources of the Colorado River Basin. Climatic Change 62:337¬363.

Chu, C., N. E. Mandrak, and C. K. Minns. 2005. Potential impacts of climate change on the distributions of several common and rare freshwater fishes in Canada. Diversity and Distributions 11:299–310.

Coleman, M. A., and K. D. Fausch. 2007. Cold summer temperature limits recruitment of Age-0 cutthroat trout in high-elevation Colorado streams. Transactions of the American Fisheries Society 136:1231–1244.

Cowley, D. E. 2007. Estimating required size for fish conservation in streams. Aquatic Conservation: Marine and Freshwater Ecosystems 17:1–14

Cowley, D. E., and V. L. Pritchard. 2003. Management of Rio Grande cutthroat trout (Oncorhynchus clarki viginalis) using hatchery stocks. Report to the New Mexico Department of Game and Fish, Santa Fe, New Mexico.

De la Hoz Franco, E., and P. Budy. 2004. Linking environmental heterogeneity to the distribution and prevalence of Myxobolus cerebralis: A comparison across sites in a northern Utah watershed. Transactions of the American Fisheries Society 133:1176–1189.

De Staso III, J., and F. J. Rahel. 1994. Influence of water temperatures on interactions between juvenile Colorado River cutthroat trout and brook trout in a laboratory stream. Transactions of the American Fisheries Society 123:289–297.

Dickerson, B. R., and G. L. Vinyard. 1999. Effects of chronic temperatures and diel temperature cycles on the survival and growth of Lahontan cutthroat trout. Transactions of the American Fisheries Society 128:516–521.

DuBey, R. J., and C. A. Caldwell. 2004. Distribution of Tubifix tubifix lineages and Myxobolus cerebralis infection in the tailwater of the San Juan River. Journal of Aquatic Animal Health 16:179–185.

DuBey, R. J., C. A. Caldwell, and W. R. Gould. 2005. Effects of temperature, photoperiod, and Myxobolus cerebralis infection on growth, reproduction, and survival of Tubifix tubifix lineages. Journal of Aquatic Animal Health 17:338–344.

DuBey, R. J., C. A. Caldwell, and W. R. Gould. 2007. Relative susceptibility and effects on performance of Rio Grande cutthroat trout and rainbow trout challenged with Myxobolus cerebralis. Transactions of the American Fisheries Society 136:1406–1414.

Dunham, J. B., G. L. Vinyard, and B. E. Rieman. 1997. Habitat fragmentation and extinction risk of Lahontan cutthroat trout. North American Journal of Fisheries Management 17:1126–1133.

Dunham, J. B., M. M. Peacock, B. E. Rieman, R.E . Schroeter, G. L. Vinyard. 1999. Local and geographic variability in the distribution of stream-living Lahontan cutthroat trout. Transactions of the American Fisheries Society 128:875–889.

Dunham, J. B., S. B. Adams, R. E. Schroeter, and D. C. Novinger. 2002. Alien invasions in aquatic ecosystems: toward an understanding of brook trout invasions and potential impacts on inland cutthroat trout in western North America. Reviews in Fish Biology and Fisheries 12:373–391.

Dunham, J. B., M. K. Young, R. E. Gresswell, and B. E. Rieman. 2003a. Effects of fire on fish populations: landscape perspectives on persistence of native fishes and nonnative fish invasions. Forest Ecology and Management 178:183–196.

Dunham, J., R. Schroeter, and B. Rieman. 2003b. Influence of maximum water temperature on occurrence of Lahontan cutthroat trout within streams. North American Journal of Fisheries Management 23:1042–1049.

Dunham, J. B., D. S. Pilliod, and M. K. Young. 2004. Assessing the consequences of nonnative trout in headwater ecosystems in Western North America. Fisheries 26:18–26.

Dunham, J. B., A. E. Rosenberger, C. H. Luce, and B. E. Rieman. 2007. Influences of wildfire and channel reorganization on spatial and temporal variation in stream temperature and the distribution of fish and amphibians. Ecosystems 335–346.

Eaton, J. G., and R. M. Scheller. 1996. Effects of climate warming on fish thermal habitat in streams of the United States. Limnology and Oceanography 41:1109–1115.

Eddy, S. 2005. Santa Fe National Forest stream temperature monitoring report, 2001-2003. Santa Fe National Forest, Santa Fe, New Mexico.

Echo, J. B. 1954. Some ecological relationships between yellow perch and cutthroat trout in Thompson Lakes, Montana. Transactions of the American Fisheries Society 84:239–248.

Enquist, C. A. F., E. H. Girvetz, and D. F. Gori. 2008. A climate change vulnerability assessment for Biodiversity in New Mexico, Part II: Conservation implications of emerging moisture stress due to recent climate changes in New Mexico. Climate Change and Adaptation Program, The Nature Conservancy, Santa Fe, New Mexico. http://nmconservation.org/dl/CC_report2_final.pdf. Accessed April 12, 2011.

Enquist, C., and D. Gori. 2008. Implications of recent climate change on conservation priorities in New Mexico. Climate Change and Adaptation Program, The Nature Conservancy, Santa Fe, New Mexico. http://nmconservation.org/dl/NMClimateChange_report1_527.pdf. Accessed April 12, 2011.

Erman, D. C., E. D. Andrews, and M. Yoder-Williams. 1988. Effects of winter floods on fishes in the Sierra Nevada. Canadian Journal of Fisheries and Aquatic Science 45:2195–2200.

Fausch, K. D., Y. Taniguchi, S. Nakano, G. D. Grossman, and C. R. Townsend. 2001. Flood disturbance regimes influence rainbow trout invasion success among five Holarctic regions. Ecological Applications 11:1438–1455.

Fausch, K. D., B. E. Rieman, M. K. Young, and J. B. Dunham. 2006. Strategies for conserving native salmonid populations at risk from nonnative fish invasions: Tradeoffs in using barriers to upstream movement. RMRS-GTR-174. U.S. Forest Service, Rocky Mountain Research Station, Ft. Collins, Colorado. http://www.fs.fed.us/rm/pubs/rmrs_gtr174.pdf. Accessed April 12, 2011.

Ferrell, S. 2006. Santa Fe National Forest Fisheries and Education Program Annual Report, 2006. U.S. Forest Service, Santa Fe National Forest, Jemez Springs, New Mexico. http://www.fs.fed.us/r3/sfe/fish/reports/anuual_reports/Annual_Report_2006.pdf. Accessed April 12, 2011.

Fink, P. R. 2008. Timber sales in Region 3 of the Forest Service. Email, February 1, 2008, to U.S. Fish and Wildlife Service, Albuquerque, New Mexico. Forester, U.S. Forest Service, Region 3, Albuquerque, New Mexico.

Frankham, R. 2007. Genetic adaptation to captivity in species conservation programs. Molecular Ecology 17: 325–333.

Frankham, R., J. D. Ballou, and D. A. Briscoe. 2002. Conservation Genetics. Cambridge University Press. Cambridge, United Kingdom.

Franklin, I. R. 1980. Evolutionary change in small populations. Pages 135-148 in M. E. Soulé and B. A. Wilcox, editors. Conservation Biology: An evolutionary-ecological perspective. Sinauer Associates, Inc. Sunderland, Massachusetts.

Gard, R. 1963. Insulation of a Sierra stream by snow cover. Ecology 44:194–197.

Garrett, G. P., and G. C. Matlock. 1991. Rio Grande cutthroat trout in Texas. Texas Journal of Science

43:405–410.

Gleick, P. H. 2000. Water: The potential consequences of climate variability and change for the water resources of the United States. Pacific Institute for Studies in Development, Environment, and Security, Oakland, California. http://www.gcrio.org/NationalAssessment/water/water.pdf. Accessed April 12, 2011.

Gresswell, R. E. 1995. Yellowstone cutthroat trout. Pages 36-54 in M. K. Young, editor. Conservation Assessment for Inland Cutthroat Trout. RM-GTR-256. U.S. Forest Service. Rocky Mountain Experimental Station, Ft. Collins, Colorado. http://www.fs.fed.us/rm/pubs_rm/rm_gtr256.pdf. Accessed April 12, 2011.

Griffith, J. S. 1988. Review of competition between cutthroat trout and other salmonids. American Fisheries Society Symposium 4:134–140

Hari, R. E., D. M. Livingstone, R. Siber, P. Burkhardt-Holm, and H. Guttinger. 2006. Consequences of climatic change for water temperature and brown trout populations in Alpine rivers and streams. Global Climate Change 12:10–26.

Harig, A. L., and K. D. Fausch. 2002. Minimum habitat requirements for establishing translocated cutthroat trout populations. Ecological Applications 12:535–551.

Harig, A. L., K. D. Fausch, and P. M. Guenther-Gloss. 2000a. Application of a model to predict success of cutthroat trout translocations in central and southern Rocky Mountain streams. Pages 141-148 in D. Schill, S. Moore, P. Byorth, and B. Hamre, editors. Proceedings of Wild Trout VII, Yellowstone National Park. Yellowstone, Montana. http://www.wildtroutsymposium.com/proceedings-7.pdf. Accessed April 12, 2011.

Harig, A. L., K. D. Fausch, and M. K. Young. 2000b. Factors influencing success of greenback cutthroat trout translocations. North American Journal of Fisheries Management 20:994–1004.

Harper, M. P., and B. L. Peckarsky. 2006. Emergence cues of a mayfly in a high-altitude stream ecosystem: Potential response to climate change. Ecological Applications 16:612–621.

Hebertson, E. G., and M. J. Jenkins. 2008. Climate factors associated with historic spruce beetle (Coleoptera:Curculionidae) outbreaks in Utah and Colorado. Environmental Entomology 37:281–292.

Henderson, R., J. L. Kershner, and C. A. Toline. 2000. Timing and location of spawning by nonnative wild rainbow trout and native cutthroat trout in the South Fork Snake River, Idaho, with implications for hybridization. North American Journal of Fisheries Management 20:584–596.

Hilderbrand, R. H., and J. L. Kershner. 2000. Conserving inland cutthroat trout in small streams: How much stream is enough? North American Journal of Fisheries Management 20:513–520.

Hoerling, M., and J. Eischeid. 2007. Past peak water in the southwest. Southwest Hydrology January/Feruary 2007: 18–19, 35. http://www.swhydro.arizona.edu/archive/V6_N1/feature2.pdf. Accessed April 12, 2011.

Horan, D. L., J. L. Kershner, C. P. Hawkins, and T. A. Crowl. 2000. Effects of habitat area and complexity on Colorado River cutthroat trout density in Uinta Mountain streams. Transactions of the American Fisheries Society 129:1250–1263.

Intergovernmental Panel on Climate Change (IPCC). 2002. Climate Change and Biodiversity. IPCC Technical Paper V. 77 pp. http://www.ipcc.ch/pdf/technical-papers/climate-changes-biodiversity-en.pdf. Accesed April 12, 2011.

Intergovernmental Panel on Climate Change (IPCC). 2007. Summary for Policymakers. In Climate Change

2007: The Physical Science Basis. Contribution of Working Group 1 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller, editors. Cambridge University Press, Cambridge, United Kingdom. http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf. Accessed November 2, 2010.

Jager, H. I., W. Van Winkle, and B. D. Holcomb. 1999. Would hydrologic climate changes in Sierra Nevada streams influence trout persistence? Transactions of the American Fisheries Society 128:222–240.

Japhet, M., J. Alves, and T. Nesler. 2007. Rio Grande cutthroat trout status review for Colorado. 2007. Colorado Division of Wildlife. Durango, Colorado.

Johnstone, H. C., and F. J. Rahel. 2003. Assessing temperature tolerance of Bonneville cutthroat trout based on constant and cycling thermal regimes. Transactions of the American Fisheries Society 132:92–99.

Keleher, C. J., and F. J. Rahel. 1996. Thermal limits to salmonid distributions in the Rocky Mountain Region and potential habitat loss due to global warming: A geographic information system (GIS) approach. Transactions of the American Fisheries Society 125:1–13.

Kundzewicz, Z.W., et al. 2007. Freshwater resources and their management. Pages 173-210 in M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden and C. E. Hanson, editors. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom. http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-chapter3.pdf. Accessed November 2, 2010.

Lake, P. S. 2000. Disturbance, patchiness, and diversity in streams. Journal of the North American Benthological Society 19:573–592.

Lassuy, D. R. 1995. Introduced species as a factor in extinction and endangerment of native fishes. American Fisheries Society Symposium 15:391–396.

Lenart, M., G. Garfin, B. Colby, T. Swetnam, B. J. Morehouse, S. Doster and H. Hartmann. 2007. Global warming in the Southwest: projections, observations, and impacts. Climate Assessment for the Southwest, University of Arizona, Phoenix, Arizona. http://www.u.arizona.edu/~mlenart/gwsw/GWSouthwest.pdf. Accessed April 12, 2011.

Martinez, J. 2006. Comanche Creek: Stream Habitat Inventory Report. U.S. Forest Service. Questa Ranger District. Carson National Forest, Questa, New Mexico.

Martinez, J. 2007. Interpreting Temperature Data for Little Costilla Creek, Comanche Creek, Vidal Creek, Chuckwagon Creek, North Ponil Creek, Costilla Creek, and McCrystal Creek of the Valle Vidal. Report. U.S. Forest Service. Carson National Forest, Taos, New Mexico.

McCullough, D. A. 1999. A review and synthesis of effects of alterations to the water temperature regime on freshwater life stages of salmonids, with special reference to Chinook salmon. EPA 910-R-99-010. U.S. Environmental Protection Agency, Region 10, Seattle, Washington. http://yosemite.epa.gov/R10/ecocomm.nsf/37aa02ee25d11ce188256531000520b3/74476bae1ae7e9fb88256b5f Accessed April 12, 2011.

McHugh, P., and P. Budy. 2005. An experimental evaluation of competitive and thermal effects on brown trout (Salmo trutta) and Bonneville cutthroat trout (Oncorhynchus clarkia utah) performance along an altitudinal gradient. Canadian Journal of Fisheries and Aquatic Science 62:2784–2795.

McIntyre, J. D. and B. E. Rieman. 1995. Westslope cutthroat trout. Pages 1-15 in M. K. Young, editor. Conservation Assessment for Inland Cutthroat Trout. RM-GTR-256. U.S. Forest Service, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, Colorado. http://www.fs.fed.us/rm/pubs_rm/rm_gtr256.pdf. Accessed April 12, 2011.

Mckenzie, D., Z. Gedalof, D. L. Peterson, and P. Mote. 2004. Climatic change, wildfire, and conservation. Conservation Biology 18: 890–902.

Meeuwig, M. H., J. B. Dunham, J. P. Hayes, and G. L. Vinyard. 2004. Effects of constant and cyclical thermal regimes on growth and feeding of juvenile cutthroat trout of variable sizes. Ecology of Freshwater Fishes 13:208–216.

Meisner, J. D. 1990a. Potential loss of thermal habitat for brook trout, due to climatic warming, in two southern Ontario streams. Transactions of the American Fisheries Society 119:282–291.

Meisner, J. D. 1990b. Effect of climate warming on the southern margins of the native range of brook trout, Salvelinus fontinalis. Canadian Journal of Fisheries and Aquatic Science 47:1065–1070.

Meisner, J. D., J. S. Rosenfeld, and H. A. Reiger. 1988. The role of groundwater in the impact of climate warming on stream salmonines. Fisheries 13:2–8.

Montgomery, D. R., E. M. Beamer, G. R. Pess, and T. P. Quinn. 1999. Channel type and salmonid spawning distribution and abundance. Canadian Journal of Fisheries and Aquatic Science 56:377–387

Moyle, P. B. 1976. Inland fishes of California. University of California Press, Berkeley, California.

Moyle, P. B., and T. Light. 1996. Biological invasions of freshwater: empirical rules and assembly theory. Biological Conservation 78:149–161.

Muhlfeld,C. C., S. T. Kalinowski, T. E. McMahon, M. L. Taper, S.Painter, R. F. Leary, and F. W. Allendorf. 2009. Hybridization rapidly reduces fitness of a native trout in the wild. Biology Letters 5:328–331.

Nakano, S., F. Kitano, and K. Maekawa. 1996. Potential fragmentation and loss of thermal habitats for charrs in the Japanese archipelago due to climatic warming. Freshwater Biology 36:711–722.

Nash, L. L., and P. H. Gleick. 1993. The Colorado River Basin and climatic change. EPA 230-R-93-009. U.S. Environmental Protection Agency, Office of Policy, Planning, and Evaluation, Climate Change Division, Washington, D.C. http://wwa.colorado.edu/colorado_river/docs/Nash_Gleick_EPA-1993.pdf. Accessed April 12, 2011.

Needham, P. R., and A. C. Jones. 1959. Flow, temperature, solar radiation, and ice in relation to activities of fishes in Sagehen Creek, California. Ecology 40:465–474.

Negron, J. F., J. D. McMillin, J. A. Anhold, and D. Coulson. 2009. Bark beetle-caused mortality in a drought-affected ponderosa pine landscape in Arizona, USA. Forest Ecology and Management257:1553–1362.

Nehring, R. B. 2007. Whirling disease investigations. Federal Aid project F-237-R14. Colorado Division of Wildlife, Ft. Collins, Colorado. http://wildlife.state.co.us/NR/rdonlyres/2DCA46FA-EAAE-43C9-8E6C-FC84481F6982/0/2007Nehringcompl
Accessed April 12, 2011.

Nehring, R. B. 2008. Whirling disease investigations. Federal Aid project F-237-R15. Colorado Division of

Wildlife, Ft. Collins, Colorado.
http://wildlife.state.co.us/NR/rdonlyres/1DC795DF-C761-42E1-AC0D-4875EEF2B121/0/WhirlingDiseaseInv
Accessed April 12, 2011.

Nehring, R. B. 2009. Whirling disease investigations. Federal Aid project F-237-R16. Colorado Division of Wildlife, Ft. Collins, Colorado.
http://wildlife.state.co.us/NR/rdonlyres/50C2DFD9-86C3-4EEE-8818-7B866C2D384A/0/NehringAdobe2.pdf.
Accessed April 12, 2011.

New Mexico Department of Game and Fish (NMDGF). 2002. Long range plan for the management of Rio Grande cutthroat trout in New Mexico. New Mexico Department of Game and Fish, Santa Fe, New Mexico.

New Mexico Environment Department (NMED). 2007. State of New Mexico Integrated Clean Water Act Report, 2006-2008. Appendix A: The List. Prepared by New Mexico Environment Department Surface Water Quality Bureau, Santa Fe, New Mexico.
http://www.nmenv.state.nm.us/swqb/303d-305b/2006-2008/2006-2008_303d-305bLIST.pdf. Accessed April 12, 2011.

New Mexico Office of the State Engineer (NMOSE). 2005. Potential effects of climate change on New Mexico. Agency Technical Workgroup Santa Fe, New Mexico.
http://www.nmenv.state.nm.us/aqb/cc/Potential_Effects_Climate_Change_NM.pdf. Accessed April 6, 2011.

New Mexico Office of the State Engineer (NMOSE). 2006. The impact of climate change on New Mexico's water supply and ability to manage water resources. Santa Fe, New Mexico.
http://www.nmdrought.state.nm.us/ClimateChangeImpact/completeREPORTfinal.pdf. Accessed April 6, 2011.

Noss, R., B. Csuti, and M. J. Groom. 2006. Habitat Fragmentation. Pages 213-252 in M. J. Groom, G. K. Meffe, and C. R. Carroll, editors. Principles of Conservation Biology. Sinauer Associates, Inc. Sunderland, Massachusetts.

Novinger, D. C., and F. J. Rahel. 2003. Isolation management with artificial barriers as a conservation strategy for cutthroat trout in headwater streams. Conservation Biology 17:772–781.

O'Neal, K. 2002. Effects of global warming on trout and salmon in U.S. Streams. Defenders of Wildlife and National Resources Defense Council, Washington, D.C.
http://www.defenders.org/resources/publications/programs_and_policy/science_and_economics/global_warmi
Accessed April 12, 2011.

Parmesan, C., and H. Galbraith. 2004. Observed impacts of global climate change in the U.S. Pew Center on Global Climate Change. http://www.pewclimate.org/docUploads/final_ObsImpact.pdf. Accessed November 2, 2010.

Parmesan, C., and J. Matthews. 2006. Biological Impacts of Climate Change. Pages 333-374 in M. J. Groom, G. K. Meffe, and C. R. Carroll, editors. Principles of Conservation Biology. Sinauer Associates, Inc. Sunderland, Massachusetts.

Paroz, Y. M. 2005. Population attributes and landscape scale habitat associations of Rio Grande cutthroat trout (Oncorhynchus clarki viginalis). M.S. thesis. New Mexico State University. Las Cruces, New Mexico.

Patten, K. A. 2007. Powerpoint presentation given at the Rio Grande cutthroat trout range-wide conservation team meeting, Taos, New Mexico, November 28, 2007. New Mexico Dpeartment of Game and Fish, Santa Fe, New Mexico.

Patten, K. A. 2009. Spreadsheet sent to Range-wide conservation team on team accomplishments in 2008. New Mexico Department of Game and Fish, Santa Fe, New Mexico.

Patten, K. A., R. Castell, S. Denny, J. Dominguez, E. Frey, R. Hansen, J. Vega, and C. M. Wethington. 2007. Final Report for Federal Aid in Sport Fish Restoration Act. New Mexico Department of Game and Fish, Santa Fe, New Mexico.

Patten, K. A., and M. B. Sloane. 2007. Comment on Rio Grande cutthroat trout status review. Letter to U.S.Fish and Wildlife Service, July 23, 2007. New Mexico Department of Game and Fish, Santa Fe, New Mexico.

Peterson, D. P., K. D. Fausch, and G. C. White. 2004. Population ecology of an invasion: Effects of brook trout on native cutthroat trout. Ecological Applications 14:754–772.

Poff, N. L., M. M. Brinson, and J. W. Day, Jr. 2002. Aquatic ecosystems and global climate change. Pew Center on Global Climate Change. http://www.pewclimate.org/docUploads/aquatic.pdf. Accessed April 12, 2011.

Preston, B. L. 2006. Risk-based reanalysis of the effects of climate change on U.S. cold-water habitat. Climatic Change. 76:91–119.

Pritchard, V. L., and D. E. Cowley. 2005. Investigation of population genetic structure and levels of introgression in Rio Grande cutthroat trout (Oncorhynchus clarki viginalis) using microsatellite markers. Contract No. 02-516-52. Report to New Mexico Department of Game and Fish, Santa Fe, New Mexico.

Pritchard, V. L., and D. E. Cowley. 2006. Rio Grande cutthroat trout (Oncorhynchus clarki viginalis): A technical conservation assessment. U.S. Forest Service, Rocky Mountain Region, Species Conservation Project. http://www.fs.fed.us/r2/projects/scp/assessments/riograndecutthroattrout.pdf. Accessed April 12, 2011.

Pritchard, V. L., K. Jones, and D. E. Cowley. 2007a. Estimation of introgression in cutthroat trout populations using microsatellites. Conservation Genetics 8:1311–1329.

Pritchard, V. L., K. Jones, and D. E. Cowley. 2007b. Genetic diversity within fragmented cutthroat trout populations. Transactions of the American Fisheries Society 136:606–623.

Raffa, K. F., B. H. Aukema, B. J. Bentz, A. L. Carroll, J. A. Hicke, M. G. Turner, and W. H. Romme. 2008. Cross-scale drivers of natural disturbances prone to anthropogenic amplification:the dynamics of bark beetle eruptions. BioScience 58:501–517.

Rahel, F. J., and W. A. Hubert. 1991. Fish assemblages and habitat gradients in a Rocky Mountain-Great Plains stream: Biotic zonation and additive patterns of community change. Transactions of the American Fisheries Society 120:319–332.

Rahel, F. J., C. J. Keleher, and J. L. Anderson. 1996. Potential habitat loss and population fragmentation for cold water fish in the North Platte River drainage of the Rocky Mountains: Response to climate warming. Limnology and Oceanography 41:1116–1123.

Rahel, F. J., and J. D. Olden. 2008. Assessing the effects of climate change on aquatic invasive species. Conservation Biology. 22:521–533.

Ray, A. J., J. J. Barsugli, K. B. Averyt, K. Wolter, M. Hoerling, N. Doesken, B. Udall, and R. S. Webb. 2008. Climate change in Colorado: a synthesis to support water resources management and adaptation. Western

Water Assessment for the Colorado Water Conservation Board. http://cwcb.state.co.us/public-information/publications/Documents/ReportsStudies/ClimateChangeReportFull.p Accessed April 12, 2011.

Reed, D. H. 2005. Relationship between population size and fitness. Conservation Biology 19:563–568.

Reed, D. H., J. J. O'Grady, B. W. Brook, J. D. Ballou, and R. Frankham. 2003. Estimates of minimum viable population sizes for vertebrates and factors influencing those estimates. Biological Conservation 113:23–34.

Regier, H. A., and J. D. Meisner. 1990. Anticipated effects of climate change on freshwater fishes and their habitat. Fisheries 15:10–15.

Regonda, S. K., B. Rajagopalan, M. Clark, and J. Pitlick. 2005. Seasonal shifts in hydroclimatology over the Western United States. Journal of Climate 18:372–384.

Rhymer, J. M., and D. Simberloff. 1996. Extinction by hybridization and introgression. Annual Review of Ecology and Systematics 27:83–109.

Rieman, B. E., and F. W. Allendorf. 2001. Effective population size and genetic conservation criteria for bull trout. North American Journal of Fisheries Management 21:756–764.

Rieman, B. E., J. Dunham, C. Luce, and A. Rosenberger. 2005. Implications of changing fire regimes for aquatic ecosystems. Pages 187-191 in L. Taylor, J. Zelnik, S. Cadwallader, and Hughes, editors. Mixed Severity Fire Regimes: Ecology and Management. Symposium Proceedings, Spokane WA. November 15-19, 2004. Association for Fire Ecology and Washington State University, Pullman, Washington. http://www.fs.fed.us/rm/pubs_other/rmrs_2005_rieman_b001.pdf. Accessed April 12, 2011.

Rieman, B. E., D. Isaak, S. Adams, D. Horan, D. Nagel, C. Luce, and D. Myers. 2007. Anticipated climate warming effects on bull trout habitats and populations across the interior Columbia River Basin. Transactions of the American Fisheries Society 136:1552–1565.

Rieman, B.E., D. Lee, J. McIntyre, K. Ovetton, and R. Thurow. 1993. Considerdation of extinction risks for salmonids. Fish Habitat Relationships Technical Bulletin 14. 12 pp.

Rieman, B. E., and J. D. McIntyre. 1995. Occurrence of bull trout in naturally fragmented habitat patches of varied size. Transactions of the American Fisheries Society 124:285–296.

Ries, R. D., and S. A. Perry. 1995. Potential effects of global climate warming on brook trout growth and prey consumption in central Appalachian streams, USA. Climate Research 5:197–206.

Rinne, J. N. 1995. Rio Grande cutthroat trout. Pages 24-27 in M. K. Young ,editor. Conservation Assessment for Inland Cutthroat Trout. RM-GTR-256. U.S. Forest Service. Rocky Mountain Experimental Station, Ft. Collins, Colorado. http://www.fs.fed.us/rm/pubs_rm/rm_gtr256.pdf. Accessed April 12, 2011.

Rinne, J. N. 1996. Short-term effects of wildfire on fishes and aquatic macroinvertebrates in the Southwestern United States. North American Journal of Fisheries Management 16:653–658.

Robinson, M. D. 2007. The ecological consequences of hybridization between native westslope cutthroat trout (Oncorhynchus clarkia lewisi) and introduced rainbow trout (O. mykiss) in Southwestern Alberta. M.S. thesis. University of Lethbridge, Alberta, Canada.

Saunders, D. A., R. J. Hobbs, and C. R. Margules. 1991. Biological consequences of ecosystem fragmentation: a review. Conservation Biology 5:18–32.

Schindler, D. W., S. E. Bayley, B. R. Parker, K. G. Beaty, D. R. Cruikshank, E. J. Fee, E. U. Schindler, and M. P. Stainton. 1996. The effects of climatic warming on the properties of boreal lakes and streams at the Experimental Lakes Area, northwestern Ontario. Limnology and Oceanography 41:1004–1017.

Schisler, G. J., E. P. Bergersen, and P. G. Walker. 2000. Effects of multiple stressors on morbidity and mortality of fingerling rainbow trout infected with Myxobolus cerebralis. Transactions of the American Fisheries Society 129:859–865.

Schoennagel,T., T. T. Veblen, and W. H. Romme. 2004. The interaction of fire, fuels, and climate across Rocky Mountain forests. BioScience 54:661–676.

Schrank, A. J. and F. J. Rahel. 2004. Movement patterns in inland cutthroat trout (Oncorhynchus clarki utah): Management and conservation implications. Canadian Journal of Fisheries and Aquatic Science 61:1528–1537.

Schrank, A. J., F. J. Rahel, and H. C. Johnstone. 2003. Evaluating laboratory-derived thermal criteria in the field: An example involving Bonneville cutthroat trout. Transactions of the American Fisheries Society 132:100–109.

Seager, R., M. Ting, I. Held, Y. Kushnir, J. Lu, G. Vecchi, H-P. Huang, N. Harnik, A. Leetmaa, N-C. Lau, C. Li, J. Velez, and N. Naik. 2007. Model projections of an imminent transition to a more arid climate in SW North America. Science 316:1181–1184.

Shaffer, M. 1987. Minimum viable populations: coping with uncertainty. Pages 69-86 in M. E. Soule, editor. Viable Populations for Conservation. Cambridge University Press. Cambridge, United Kingdom.

Shemai, B., R. Sallenave, and D. E. Cowley. 2007. Competition between hatchery-raised Rio Grande cutthroat trout and wild brown trout. North American Journal of Fisheries Management 27:315–325.

Shepard, B. B. 2004. Factors that may be influencing nonnative brook trout invasion and their displacement of native westslope cutthroat trout in three adjacent southwestern Montana streams. North American Journal of Fisheries Management 24:1088–1100.

Shuter, B. J., and J. D. Meisner. 1992. Tools for assessing the impact of climate change on freshwater fish populations. GeoJournal 28:7–20.

Sloat, M. R., B. B. Shepard, and R. G. White. 2005. Influence of stream temperature on the spatial distribution of Westslope cutthroat trout growth potential within the Madison River Basin, Montana. North American Journal of Fisheries Management 25:225–237.

Smith, K., and M. E. Lavis. 1975. Environmental influences on the temperature of a small upland stream. Oikos 26:228–236.

Stewart, I.T., D.R. Cayan, and M.D. Dettinger. 2004. Changes in snowmelt runoff timing in western North America under a ‘business as usual’ climate scenario. Climatic Change 62:217–232.

Stewart, I. T., D. R. Cayan, and M. D. Dettinger. 2005. Changes toward earlier streamflow timing across Western North America. Journal of Climate 18: 1136–1155.

Sublette, J.E., M.D. Hatch, and M. Sublette. 1990. The Fishes of New Mexico. University of New Mexico Press, Albuquerque, New Mexico.

Swetnam, T. W., and C. H. Baisan. 1994. Historical fire regime patterns in the Southwestern U.S. since AD

1700. Pages 11-32 in C.D. Allen, technical editor. Fire Effects in Southwestern Forests, Proceedings of the Second La Mesa Fire Symposium. RM-GTR-286. U.S. Forest Service, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, Colorado. http://www.fort.usgs.gov/Products/Publications/3199/3199.pdf. Accessed April 12, 2011.

Thompson, K. G., R. B. Nehring, D. C. Bowden, and T. Wygant. 1999. Field exposure of seven species or subspecies of salmonids to Myxobolus cerebralis in the Colorado River, Middle Park, Colorado. 1999. Journal of Aquatic Animal Health 11:312–329.

Udall, B., and G. Bates. 2007. Climatic and hydrologic trends in the Western U.S.: A review of recent peer reviewed research. Intermountain West Climate Summary. January 2007:2–8. http://wwa.colorado.edu/IWCS/archive/IWCS_2007_Jan_feature.pdf. Accessed April 12, 2011.

U.S. Forest Service (Forest Service). 2006. Rio Grande cutthroat trout accomplishments. Southwestern Region – Albuquerque, New Mexico. Rocky Mountain Region – Golden, Colorado. Report to U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

U.S. Department of the Interior. 2009. The meaning of “Foreseeable Future” in Section 3(20) of the Endangered Species Act. Memorandum M-37021, January 16, 2009. Department of the Interior Office of the Solicitor to U.S. Fish and Wildlife Service, Arlington, Virginia. http://www.doi.gov/solicitor/opinions/M-37021.pdf. Accessed April 12, 2011.

Wagner, E. J., R. E. Arndt, and M. Brough. 2001. Comparative tolerance of four stocks of cutthroat trout to extremes in temperature, salinity, and hypoxia. Western North American Naturalist 61:434–444.

Westerling, A. L., H. G. Hidalgo, D. R. Cyan, and T. W. Swetnam. 2006. Warming and earlier spring increase Western U.S. forest wildfire activity. Science 313:940–943.

Western Regional Climate Center. 2011. Jemez Springs, New Mexico: period of record monthly climate summary. http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?nmjeme Accessed April 22, 2011.

Young. M. K., and P.M. Guenther-Gloss. 2004. Population characteristics of greenback cutthroat trout in streams: Their relation to model predictions and recovery criteria. North American Journal of Fisheries Management 24:184–197.

Young, M. K., P. M. Guenther-Gloss, and A. D. Ficke. 2005. Predicting cutthroat trout (Oncorhynchus clarkii) abundance in high-elevation streams: Revisiting a model of translocation success. Canadian Journal of Fisheries and Aquatic Science 62:2399–2408.

Approval/Concurrence:

Lead Regions must obtain written concurrence from all other Regions within the range of the species before recommending changes, including elevations or removals from candidate status and listing priority changes; the Regional Director must approve all such recommendations. The Director must concur on all resubmitted 12-month petition findings, additions or removal of species from candidate status, and listing priority changes.

Approve: 05/30/2012
Date

Concur: 11/06/2012
Date

Did not concur: ______________________________ ______________
Date

Director's Remarks: